LEVEL II

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JOINT SERVICES EVALUATION PLAN FOR PREFERRED AND ALTERNATE EXPLOSIVE FILLS FOR PRINCIPAL MUNITIONS.

JOINT SERVICES EXPLOSIVE FILL PROGRAM (LONG RANGE)
FINAL REPORT ON THE USE OF EMERGENCY FUNDS.

VOLUME IV. JOINT SERVICE SAFETY AND PERFORMANCE MANUAL FOR QUALIFICATION OF EXPLOSIVES FOR MILITARY USE.

(9) Final rept.

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Prepared by

JOINT TECHNICAL COORDINATING GROUP

for

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This document presents a compilation of Joint Service test procedures for qualifying primary, booster and main charge explosives for interim development and final application in military end-items. These qualification procedures will be required for any explosive under consideration by any of the military services.

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JOINT TECHNICAL COORDINATING GROUP FOR MUNITIONS DEVELOPMENT WORKING PARTY FOR EXPLOSIVES

Reply to
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Since this document was prepared in 1971 several organizational changes have occurred which will require correction in an up-dated version of this manual. For example, the Joint Technical Coordinating Group involved is now the JTCG/Munitions Development; the Naval Ordnance Systems Command responsibilities described are now incorporated in those of the Naval Sea Systems Command; those of the Explosives Division, Picatinny Arsenal are now with the Energetic Materials Division, US Army Armament Research and Development Command, Dover, NJ.

Although distributed as an interim document the manual continues to be the basic document describing the tests and criteria used by the three services to qualify explosives for military use. New tests are continuing to be refined. Some of these advances are described in ARRADCOM Special Publication ARLCD-77004 (September 1977) "Proceedings of the Conference on the Standardization of Safety and Performance Tests for Energetic Materials" Dover, N.J.

As a consequence, the manual is under revision to incorporate the changes and to extend the coverage to propellant and pyrotechnic substances. NATO-wide discussions are also being conducted to develop principles and a manual of wider acceptability.

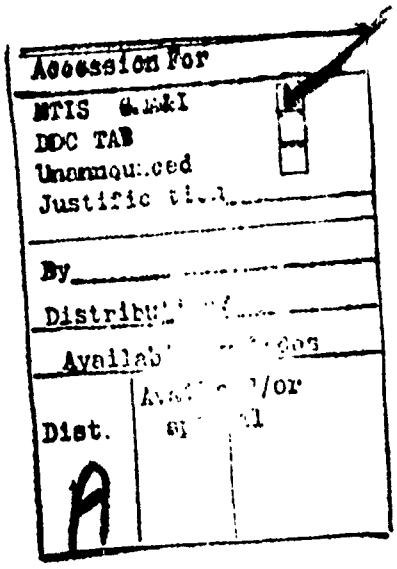
This is a massive task which may take some years to accomplish. In the interim period the JTCG/MD Working Party for Explosives will be glad to provide advice or assistance in the conduct of qualification test procedures that will meet US military approval. Contact with

the Working Party can be made through Dr. Raymond F. Walker (Chairman) or Dr. Harold Matsuguma (alternate) in the Energetic Materials Division. Users in particular are urged to submit suggestions to replace, improve or supplement the tests described.

The following pages are provided to indicate the authority for the statements made in the manual.

Raymond F. Walker

DR. RAYMOND F. WALKER
Chairman, JTCG/MD
Working Party for Explosives



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ADDENDUM

The following pages are provided to indicate the authority for statements made in this Manual. This is Volume IV of the subject report and action has been initiated to convert the text into a Joint Services Military Standard.

In its present form the volume is an interim document. All users are urged to submit suggestions to the JTCG/MD Working Party for Explosives to replace existing tests, introduce improved tests or to improve the validity of the assessment process.

Raymond F. Walker

DR. RAYMOND F. WALKER
Chairman, JTCG/MD
Working Party for Explosives

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JOINT AGREEMENT
ON
JOINT SERVICES EXPLOSIVE FILL PROGRAM (LONG RANGE)
FINAL REPORT ON THE USE OF EMERGENCY FUNDS

We approve the report of our Joint Technical Coordinating Group for Air Launched Non-Nuclear Ordnance and agree to forward the report to our Service headquarters to enlist their support in the continuation of this program.

HENRY A. MILEY, JR.
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Commanding General
U. S. Army Materiel Command

I. C. KIDD, JR.
Admiral, USN
Chief of Naval Material
Naval Material Command

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GEORGE S. BROWN
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Air Force Systems Command

19 September 1972
Date

JOINT SERVICES EVALUATION PLAN FOR PREFERRED AND ALTERNATE EXPLOSIVE FILLS FOR PRINCIPAL MUNITIONS

Joint Services Explosive Fill Program (Long Range)
Final Report on the Use of Emergency Funds

VOLUME I Administrative Summary (U)

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Date: 12 May 1972

JOINT SERVICES EXPLOSIVE FILL PROGRAM (LONG RANGE)

FINAL REPORT ON THE USE OF EMERGENCY FUNDS

This report has been approved by the principal members of the Joint Technical Coordinating Group for Air Launched Non-Nuclear Ordnance.

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JOINT SERVICES EVALUATION PLAN FOR PREFERRED AND ALTERNATE EXPLOSIVE FILLS FOR PRINCIPAL MUNITIONS

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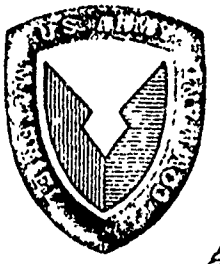
VOLUME I - Administrative Summary



Prepared by

JOINT TECHNICAL COORDINATING GROUP

for

AIR LAUNCHED NON-NUCLEAR ORDNANCE

Note: Numerous improvements have been made in this Manual since prepared in September 1971 and they can be obtained by reference to NAVORD OD44811, pending revision of this document.

JOINT SERVICES EVALUATION PLAN FOR PREFERRED AND ALTERNATE EXPLOSIVE FILLS FOR PRINCIPAL MUNITIONS

Joint Services Explosive Fill Program (Long Range)
Final Report on the Use of Emergency Funds

VOLUME IV Joint Service Safety and Performance Manual for Qualification of Explosives for Military Use (U)

Prepared by: Joint Technical Coordinating Group for Air Launched Non-Nuclear Ordnance Working Party for Explosives

Published by: The Naval Weapons Center
China Lake, California

Date: 8 September 1971

ABSTRACT

This document presents a compilation of Joint Service test procedures for qualifying primary, booster and main charge explosives for interim development and final application in military end-items. These qualification procedures will be required for any explosive under consideration by any of the military services.

PREFACE

This manual constitutes Volume IV of the four volume final report on the use of DOD emergency funds to initiate the long range Joint Services Explosives Fill Program. The funds were assigned to the US Army Project 1T562603A559.

As indicated in the FOREWORD, in its present form the document must be considered an interim manual, subject to continuing review analysis and improvement. Nevertheless, it is a significant step forward and has already played a role in other facets of the Joint Services Explosives Fill Program.

Raymond F. Walker

RAYMOND F. WALKER
Chairman, Working Party for Explosives
Joint Technical Coordinating Group
Air-Launched Non-Nuclear Ordnance

FOREWORD

This document presents a compilation of Joint Service test procedures for qualifying primary, booster, and main charge explosives for use in service applications and in development programs leading to such applications (interim qualification). Test procedures and criteria for final qualification of explosives in their intended application are also included. These qualification procedures will henceforth be required for any explosive to be used by any of the military services. Additional guidance will be forthcoming concerning the qualification of liquid and slurry explosives.

Some of the tests are listed as mandatory and must, therefore, be performed. For these, suggested passing criteria have been established and it is expected that these criteria will be used by all services. An individual service retains the right to impose additional passing criteria to fit its own more stringent requirements in specific cases.

This document is intended to be a viable guide, subject to regular review and updating, as a greater understanding is generated on the behavior, properties and testing of explosives. New tests will be included to fill gaps or to replace existing tests and users of this document are encouraged to submit test procedures for consideration.

This document contains the following:

Appendixes:

ACKNOWLEDGMENT

This document represents the combined efforts of Air Force, Army and Navy personnel. The coordinated tri-service effort was funded under the JTCG ALNNO/WPE chaired by Dr. Raymond Walker. A working committee was set up for establishing tri-service test procedures and qualification guidelines for explosives to be used by any of the services as well as tri-service evaluation methods for performance of military explosives. The committee consisted of Dr. Harold Matsuguma of Picatinny Arsenal; Dover, New Jersey; Dr. Larry Elkins of Eglin Air Force Base, Florida, and Dr. Harold Grytinq of the Naval Weapons Center, China Lake, California (Chairman). In addition a number of other people contributed to the manual. Some contributed as the authors of referenced or included procedures; others contributed through suggestions and review of procedures. The Navy group that contributed to preparation of the document which formed the nucleus for this tri-service document (OD 44811) are listed in the foreword. R. Beauregard, Naval Ordnance Systems Command (NOSC), was particularly helpful in working up the precursor document. Acknowledgment for OD 44811 follows:

The Naval Ordnance Systems Command gave NWC responsibility to prepare a safety and performance manual for qualification of explosives for service use. A committee was formed consisting of R. Beauregard, NOSC 0332; James Ablard, NOL, White Oak; William McBride, NWS, Yorktown; V. Philipchuk, NWL, Dahlgren; and H. J. Grytinq, NWC, China Lake (Chairman).

This group met to establish the scope and overall content and discussed content of each chapter with chapter authors. Previous work had enabled a booster explosive document to be drafted and considered for tri-service use with fuze committee backing. This became Chapter III, the interim qualification document for booster explosives.

Those responsible for individual chapters were:

Chapter I. I. Kabik, NOL

Chapter II. I. Kabik, NOL

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The assistance of R. J. Morey, Code 4551 (NWC), in organizing and editing this document is appreciated.

INTRODUCTION

The Department of Defense supports explosives R&D programs in each of the three services. As these programs are productive, new explosives are generated in response to goals set to obtain improved explosives to satisfy future and ongoing needs. Some explosives may be of high interest to consider for concurrent development with applications programs and it is essential that the capabilities and limitations of the explosive be adequately determined.

As a guideline for weapons designers and as an aid to explosives researchers and engineers, this document describes:

1. Evaluation procedures which must be run (discriminatory tests) before an explosive can be selected for final evaluation in a warhead.

2. Additional background information concerning the explosive which is desirable but not mandatory.

3. Criteria for passing the tests outlined herein.

This information is presented for primary, booster, and main charge explosives and is mainly for storable explosives and not for explosives which may be made up and used the same day. Performance tests listed are referenced or presented herein, including both those essential and those considered desirable. These are intended to give designers better knowledge as to the type of application best fulfilled by a particular explosive and vice versa.

During the preparation of the documents for interim qualification of primary, booster, and main charge explosives, concern was repeatedly voiced that the explosive formulation made in production would not be exactly the same as that subjected to the qualification tests. Compositions covering the probable range of variance in density, composition, particle size, etc. expected to occur during production should be made and tested; however, the added cost may be prohibitive during interim qualification. It is therefore recommended that any material passing

these tests be examined thoroughly at the time of consideration for use in a warhead or other application so that reasonable assurance can be given that the product will be acceptable for the parameters considered. The range considered should cover expected production variability. It is recommended that this variability be further checked as to meeting the requirements of WR-50 by means of designed experiments including expected variable extremes. Some of this information would normally be obtained during development.

It is necessary that several batches of the explosive composition be prepared so that processability by the intended production method is reasonably assured. The composition should be successfully scaled up to at least 100 pounds for main charge explosives, 25 pounds for booster explosives and to a logical production size appropriate for the type of primary explosive, if the method is a noncontinuous process, before it can be considered as having completely satisfied the requirements for interim qualification. Unless otherwise specified in this document, with the evaluation procedure prescribed at least three batches of approximately the same composition should be tested and should pass the sensitivity and stability tests as required for each type explosive before the composition is considered safe. The composition is considered unacceptable if one or more of the batches fail these tests.

It is further expected that any major problems in successful processing by the method of intended production should be worked out so that there are no known outstanding production problems to be solved when interim qualification is granted.

The explosive composition should be sent to the Bureau of Explosives of the Association of American Railroads for appropriate classification or classified by the appropriately recognized service agency, such as ORD-048, on the basis of similar tests so that suitable criteria for establishing safe shipment methods are clear.

This Joint Service document presents a compilation of test procedures from the three services that have been agreed upon for qualifying primary, booster, and main charge explosives for consideration for use in service application (interim qualification) and also those test procedures and criteria for evaluation of explosives for final qualification of the explosive in its intended application. These qualification procedures will henceforth be required for any explosive to be used by any of the military services.

Some of the tests are listed as mandatory and must therefore be performed. For these, suggested passing criteria have been established and are presented. It is accordingly expected that these criteria will be used by all services. The individual service reserves the right to change the passing criteria to fit their own perhaps more stringent requirement in specific cases or to devise more appropriate criteria.

Relationships of organizations in the three services to the approval of explosives and of explosives in weapons.

Although the required tests for qualification will be the same or nearly so except for occasional more stringent requirements for certain applications, the three services individually qualify the explosive they use. For the Navy the Ordnance Systems Command has full responsibility for explosives development and qualification both interim qualification and final qualification in the weapon.

The Explosives and Pyrotechnic Branch, ORD 0332 is responsible for making recommendations for approval to COMNAVORD whereas the Safety Division ORD 048 has overall weapon systems safety responsibility per NAVORDINST 8020.11. The Weapons Systems Explosives Safety Review Board must approve of every Navy weapon prior to its release for service use. Further delineation of Navy responsibilities in NAVORD are given in several instructions summarized in NAVORD INST 8020.11, included in the manual and in NAVMATINST 8020.1D.

For the Army, interim qualification is granted by the Explosive Division, Feltman Research Laboratory (FRL) Picatinny Arsenal, Dover N. J. This qualification will be granted on the basis of successful passing of required

tests of OD 44811 and its Joint Service successor and any other tests from the background information sections of the Manual that the Explosives Division deem necessary. Final qualification requires WR-50 (Reference 1 of 6-2) type tests as indicated in this Joint Services manual (and OD 44811) and in addition those tests required for special applications from the publication "Army Materiel Test Procedures" Picatinny Arsenal. This is a rather large group of booklets which cover specialized tests for various Army applications. Procedure 4-1-001 describes cognizant Army Agencies and offices for weapons systems ammunition and explosives for their life cycle. Environmental tests are covered in more detail in AR 70-38. A large number of these test procedures are the same MILSTD 810B and MILSTD 331 procedures referred to in WR-50. The final explosives approval and qualification in the munition is given by the Army Munitions Command.

The Air Force grants interim explosives qualification through its Air Force Armament Laboratory, Eglin Air Force Base, Florida and final qualification through the Air Force Non-Nuclear Munitions Safety Group (NNMSG) in accordance AFR 127-102 of 7 March 1972. The Air Force requires the use of the same evaluation procedures as the other services, viz., the Joint Service Manual.

The Naval Ordnance Systems Command, ORD-0332, will make the final judgment concerning the granting of interim qualification based upon their interpretation of the results of the tests described by this document for the Navy and the AFATL/DLGS for the Air Force. The Army acceptance of an explosive in a munition is predicated on successful demonstration of superior performance in the primary munition and successful completion of manufacturing and field test regimens.

GENERAL DEFINITIONS

Primary Explosives are those sensitive formulations or compounds such as Lead Azide or Lead Styphnate which are used principally as initiating agents in explosive trains. These sensitive explosives are normally separated from the booster explosive by the interrupter or safety and arming device of the fuze or exploder.

Booster Explosives are compounds or formulations such as tetryl or CH-6 which are used to transmit and augment the detonation reaction (initiated by the primary explosive) with sufficient energy to initiate a stable detonation in the main-charge explosive.

Main Charge Explosives are compounds or formulations such as TNT, Composition B, or H-6 which are used as the final charge in any explosive application. These explosives, because of their insensitivity, ordinarily require initiation by a booster explosive. For this document explosives do not include pyrotechnics or propellants unless they are used as the principle energy source for destructive effects.

Non-Certified Explosives are compounds or formulations which are neither service approved nor interim qualified. For the purpose of this document, these include both explosives still under development and explosives which, although they may be used commercially or by other services, have not been formally approved or interim qualified.

Service Approved Explosives are compounds or formulations which have been approved by the appropriate service command.

Interim Qualified Explosives are compounds or formulations that have not been approved for service use in specific applications, but have been approved for further development leading toward an application.

SAFETY

General Safety Precautions

The loading, assembly, and handling of any item covered by this document, and the subassemblies thereof, involve hazardous operations and therefore require suitable explosives safety precautions. Use of this document will not be construed as to relieve the contractor or manufacturer of responsibility for the safety of his operations. Listed below are certain minimum provisions which, in combination with DOD 4145.26M (DOD Contractors' Safety Manual for Ammunition and Related Dangerous Material, October 1968) a contractor or manufacturer should observe in order to fulfill his responsibility for safety. At government plants these provisions are mandatory. Such other warnings and precautions, pertinent to the operational effectiveness or safety during use or loading of the specified item, are included in the detailed technical requirements of the document.

1. All loading operations should be conducted in a neat and orderly manner.

2. Safe equipment and methods should be utilized for transporting and handling explosives and loaded parts. Where required, remote control barricaded handling equipment shall be used for explosives operations such as mixing, pouring, weighing, charging, sifting, drying, pressing, casting, crimping, etc.

3. Personnel handling detonators, primers, delay elements, lead-ins, boosters, and related parts that affect functioning, should insofar as practicable, avoid using bare fingers or improper equipment in order to prevent damage, corrosion, or deterioration from perspiration or other contaminating deposits.

4. The exposure of explosive materials and related parts should be so controlled as to minimize the absorption of moisture from the atmosphere or other sources during loading and handling operations.

5. All explosives and completely or partially loaded items should be stored in suitable storage magazines located in accordance with the American Table of Distances (ATD) or other applicable safety standards; and, while in process, in safety lockers and chests if in loading rooms, or in adequate ready or service magazines located in accordance with Intraplant distances when outside of loading rooms.

6. Proper care must be exercised at all times to protect personnel from accidents, fires or explosions, and to limit damage to equipment and loading areas. In this connection, the precautionary measures in the following paragraphs should be observed.

a. Employ properly proportioned and properly located protective barricades, screens or shields at all required points.

b. Keep only minimum limited quantities of explosives and completed or partially loaded parts present at each stage of operation.

c. Keep explosives and explosive parts in approved covered receptacles with covers in place when material is not being taken out of or put into the receptacles. Where necessary, receptacles should be conductive to ground electrostatic charges.

d. Protect operations from electrostatic charges by effectively grounding all machinery, equipment, and fixtures; and, where necessary, employ suitable grounded conductive coverings for floors, work benches and tables, and workers' conductive shoes. Workers' clothing of a type to minimize the accumulation of static charges should be employed. Fabrics such as silk and nylon, which promote static charge generation, should be avoided. Additional grounding devices, such as grounded bracelets for workers, should be employed where operations are conducted with items that are unusually sensitive to initiation by static electricity. Such items include initiating explosives, tracer mixtures, and

low-energy-type electric primers, detonators, and squibs. The latter types of items should have the free ends of lead wires bared and twisted together, and be packed in relatively small groups wrapped in bare non-insulated aluminum foil or other uncoated metal foil. During assembly and processing operations such sensitive electric items should be short circuited by clips or other devices until installed with safety shunt in the final device. Additional precautions for these items should include mechanical shielding to contain or deflect fragments and blast, also electrical shielding of these items from induced electric currents generated by sources such as lightning, static charges, radiations from communications apparatus, radar, or high frequency heating apparatus, etc. Where necessary for safety, humidity of workrooms should be increased, as required, to lessen electrostatic effects without excessive moisture absorption.

e. Protect all explosive operations from effects of electric current originating from equipment such as soldering irons, heaters, switches, wiring, motors, lights, test instruments, etc., by suitable insulation, grounding, separation, or shielding.

f. Enforce, where necessary, the wearing of suitable safety footwear, gloves, goggles, respirators, and impregnated garments to protect personnel against burns, poisoning and associated industrial hazards.

g. Allow no fires or exposed electrical or other sparking equipment, and little or no flammable material to be present in loading, handling, and storage spaces. Enforce proper "Match" and "No Smoking" rules where necessary.

h. Enforce good housekeeping and maintain effective policing, inspection, and supervisory methods throughout the loading area and surroundings. Employ effective cleaning methods periodically to minimize the accumulation of explosives or explosive dust and other contamination upon, and assure its removal from floors, walls, ceilings, ledges, tables, benches, piping, and equipment or the items loaded; also, clean up any

spilled material immediately. Employ an adequate ventilation system to prevent an accumulation of toxic or flammable vapors in manufacturing or storage areas.

CONTENTS

1. SCOPE

1.1 Purpose. This chapter establishes criteria for the acceptance of primary explosives for use in Navy weapons. Initial and intermediary charges for primers, detonators, relays, electric matches, delays, explosive bolts, explosive switches, explosive actuators, explosive valves, explosive cutters, and explosive pistons are included when they do not qualify under either Chapter III or Chapter V of this document.

1.2 Limitation. The condition of having satisfactorily passed the tests described herein is necessary but not sufficient for a primary explosive material to be approved for service use. Final approval for use in weapons must be obtained from the Naval Ordnance Systems Command upon satisfactory completion of the appropriate tests of Chapter II of this document.

1.3 Applicability. This document is to be applied as a qualification standard for primary explosives and not as a procurement or quality control standard. It is necessary, however, that explosives qualifying under this document for the applications of paragraph 1.1 above contain in their procurement specifications tests to assure continued control of the properties as delineated in this standard. When such tests are not included, the requirements of this standard, at the discretion of the procuring activity, may be invoked to demonstrate that the explosive as procured still qualifies under this document.

1.4 Applicable Documents.

1.4.1 Specifications.

JAN-P-408	Pentolite 50/50.
MIL-L-757	Lead Styphate.
MIL-L-3055	Dextrinated Lead Azide.

1.4.2 Reports.

Applied Mathematic Panel of the National Defense Research Committee (AMP Report No. 101.1R, SRG-P No. 40).

Naval Ordnance Laboratory. The Development of Impact Sensitivity Tests at the Explosives Research Laboratories, Bruceton, Penn. During the Years 1941-1945. White Oak, Md., 6 March 1956. (NAVORD Report 4236, publication CONFIDENTIAL.)

Naval Ordnance Laboratory. The Electrostatic Spark Sensitivity of Bulk Explosives and Metal/Oxidant Mixtures, by R. M. H. Wyatt. White Oak, Md., 1 June 1969. (NAVORD Report 6632, publication CONFIDENTIAL.)

Naval Ordnance Laboratory. The Electrostatic Spark Sensitivity of Various Organic Explosives and Metal/Oxidant Mixtures. White Oak, Md., 7 March 1966. (NOLTR 65-124, publication CONFIDENTIAL.)

2. TERMS AND DEFINITIONS

2.1 Definitions. The following specialized terms and definitions are applicable to the requirements of this document.

2.1.1 Primary Explosive. For the purposes of this document, a primary explosive is a single explosive compound or a mixture that does not meet the requirements of one or more of the tests specified in paragraphs 5.1, 5.2, 5.3, 5.5, 5.7, or 5.8 of Chapter III of this document.

2.1.2 Explosive (Material). As used herein, the term "Explosive", or "Explosive Composition" implies not only a specific composition, but a specific particle size distribution, purity, and process of manufacture. When a specification includes several variants as indicated by types, grades, classes, etc., each permutation of type, grade, class, etc., shall be considered to be a different explosive. When foreign materials such as binders, lubricants, etc., are added at the point of loading, each explosive material with each such additive in each proportion will be considered to be a different explosive, and each is subject to the qualification provisions of Sections 4 and 5.

2.1.3 Candidate Explosive. As used herein, the term "candidate explosive" is any explosive material being evaluated in accordance with this document.

2.1.4 Test. As used herein, the term "test" is the complete series of trials or replicates specified.

2.1.5 Trial. The term "trial" means the application of a stimulus to a single specimen of explosive.

2.1.6 Representative Sample. Sampling procedures may be varied to accomodate circumstances. However, where feasible, part of each representative sample shall be drawn from each container and from various locations within each container. The sample shall not be blended before use in tests.

2.1.7 Sub-Sample. Where part of each sample, as specified above, is drawn from each container and/or from various locations within each container, each such part is considered to be a "sub-sample".

3. GENERAL REQUIREMENTS

3.1 Basic. All primary explosives used in weapons must meet all of the mandatory requirements given in Section 4. Each explosive material, as defined in paragraph 2.1.2 must meet these requirements. In addition, Section 5 gives tests to provide desirable background information.

3.2 New Compositions. In addition to passing the tests described in the mandatory requirements, each compound or mixture proposed for use as a primary explosive shall be studied for the possibility of reactions with containers or contaminants, or phase transitions under anticipated conditions of use. Experiments shall be performed to determine the probability of such changes and their effect upon stability and sensitivity as determined by tests described in Section 4.

3.3 Explosives Description and Analysis. A description of what constitutes the explosive (including its composition analysis) shall be presented when applying for an interim qualification. The explosive shall be adequately defined and shall have met the requirements of this chapter.

3.4 Specimens, General Requirements. The following paragraphs are directed toward the preparation of specimens of each candidate explosive in a physical or chemical state similar (as is practical and compatible with test procedures) to the physical and chemical state in which the candidate explosive is to be used. Where, within the latitude of the requirements as given, it is necessary to exercise judgement regarding specimen preparation, this objective shall form the basis of such judgement.

3.4.1 Sub-Samples. To the extent that it is practical and feasible, sub-samples shall be kept separate, and equal numbers of specimens for each test described under Mandatory Requirements (Section 4) shall be drawn from each sub-sample of a candidate explosive.

4. MANDATORY REQUIREMENTS

4.1 Vacuum Thermal Stability and Chemical Decomposition Test.

A 100°C vacuum thermal stability and chemical decomposition test shall be run in triplicate on a composite sample of the candidate primary explosive. The test specimens shall be held at the 100°C temperature for a period of 48 hours. This time may be exceeded but no candidate explosive shall be considered to have passed the requirements of this test if the time at 100°C is less than 48 hours. The apparatus and procedure for running the test is given in the following paragraphs. (Also see Specification JAN-P-408.)

4.1.1 Calibration. Determine the volume in ml of the 15.5 cm heating tube (Fig. 1-1) by adding mercury from a buret until the tube is filled to the level at which the ground glass joint of the capillary tube will make contact with the mercury. Subtract from the indicated buret reading, the volume of explosive used in the test (0.1 ml). The difference shall be represented by the symbol A. Transfer 7.0 ml of mercury to the cup at the lower end of the capillary tube. Clamp the tube in an upright vertical position, and measure the height in mm of the mercury column in the capillary tube (approximately 25 mm). Measure the length in mm of each of the 3 parts of the capillary tube and add these values

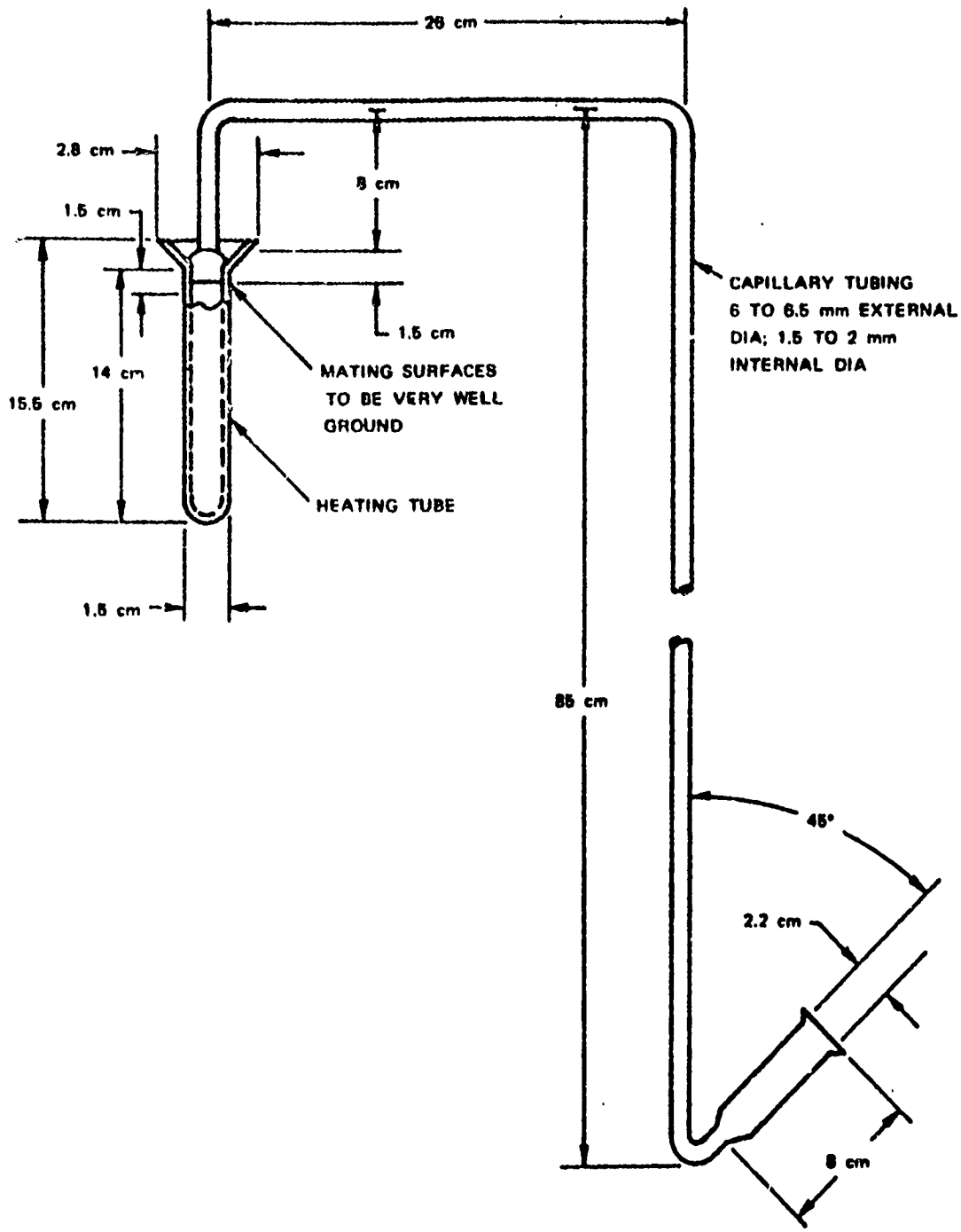


FIG. 1-1. Vacuum Thermal Stability Test.

to obtain total length. From the total length subtract the height of the mercury column in the capillary tube as previously obtained. Represent this difference by the symbol B_1. From the total length subtract the height of the column of mercury in the capillary tube measured at the end of the test described in paragraph 4.1.2. Represent this difference by the symbol B. Determine the capacity of the capillary tube per unit of length as follows: Transfer an accurately weighed sample of approximately 10 grams of mercury to the cup at the lower end of the capillary tube. Manipulate the tube so that when it is horizontal mercury is contained in the continuous section of the longest part of the tube, and measure the length of the mercury column. Repeat this procedure twice with the mercury in 2 other parts of the long section of the tube. Calculate the average of the 3 measured lengths of the mercury column. Represent the unit capacity in ml per mm of the capillary tubing by the symbol C. This can be obtained from the formula

$$C = \frac{W}{DL}$$

where

C = unit capacity of capillary tubing in ml per mm
W = grams of mercury
D = density of mercury at temperature of determination
L = average measured lengths of mercury column in mm.

4.1.2 Test Procedure. Transfer a 0.2 ± 0.001 gm sample, dried at 65°C for 2 hours, to the heating tube of the apparatus shown in Fig. 1-1. Connect the capillary tube to the heating tube and seal the connection with 1 ml of mercury. Clamp the apparatus so that the long section of the capillary tube is in a nearly vertical position and the lower end rests on a solid support. Transfer 7.0 ml of mercury to the cup at the lower end of the capillary tube and evacuate the system until the pressure is reduced to approximately 5 mm of mercury. Disconnect the pump and measure the total vertical height of the column of mercury in the capillary tube. Measure and subtract the vertical height of the mercury

in the cup. The difference shall be represented by the symbol H_1. Note the room temperature (t_1) and the barometric pressure. Subtract the value H_1 from the barometric pressure in mm. Represent this difference by the symbol P_1. Insert the heating tube in a constant temperature bath maintained at 100 ± 0.5°C. Maintain the heating tube at temperature for 48 hours. Remove the heating tube from the bath and allow it to cool to room temperature. Measure the total vertical height of the column of mercury in the capillary tube and subtract the vertical height of the mercury in the cup. This difference shall be represented by the symbol H. Note the room temperature (t) and the barometric pressure. Subtract the value H from the barometric pressure in mm. Represent this difference by the symbol P. Remove the heating tube and the sample from the capillary tube and retain for the tests of paragraph 4.1.4.

4.1.3 Calculation of Gas Evolved. Calculate the volume of gas (V) in ml, at standard conditions, liberated in the test described in paragraph 4.1.2 using the value represented by the symbols described in the preceding paragraphs in the following formula:

$$V = \left[A + C(B - H)\frac{273P}{760(273 + t)}\right] - \left[A + C(B_1 - H_1)\frac{273P_1}{760(273 + t_1)}\right]$$

4.1.4 Analysis. A chemical and/or physical analysis shall be made of the material remaining in the heating tube to determine quantitatively the degree of chemical decomposition that has occurred in the test. Since no single analytical procedure can be given for all primary explosive, it will be the responsibility of the organization proposing the candidate primary explosive to provide a procedure meeting the approval of the Naval Ordnance Systems Command. The proposed procedure shall be capable of detecting not less than a 0.075 percent degradation in the primary explosive or any of its major constituents if the primary explosive is a mixture.

4.1.4.1 The tests of paragraph 4.1.4 may be waived if, to the satisfaction of the Naval Ordnance Systems Command, it is shown that the decomposition of each 0.1 gram of candidate primary explosive will be accompanied by the liberation of at least 2 ml (at STP) of permanent gas.

4.1.5 Qualification Criterion. The volume of gas evolved as calculated under paragraph 4.1.3 shall be divided by the weight of the sample. This figure yields the ml of gas evolved per gram per 48 hours. To be acceptable as a primary explosive, none of the triplicate samples shall yield a value of more than 2.0 ml gas/gram/48 hours.

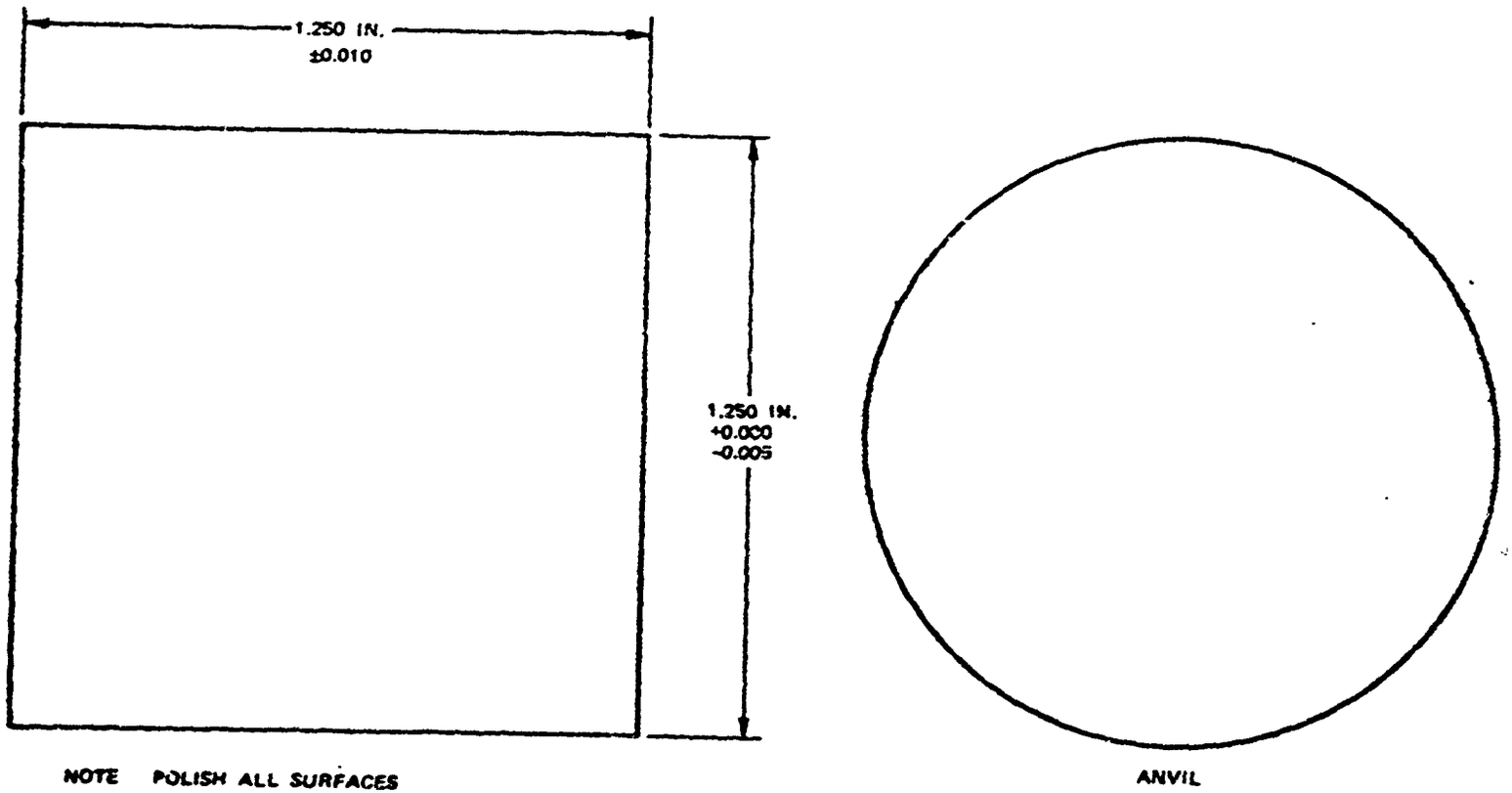
4.1.5.1 In those cases where the test of paragraph 4.1.4 applies, the candidate primary explosive shall be considered acceptable if not more than 0.1 percent degradation has occurred in the explosive or any of its major constituents.

4.2 Impact Sensitivity.

A dry representative sample of a candidate primary explosive shall be subjected to an impact sensitivity test using ERL type 12 tools as described in NAVORD Report 4236. The results shall be compared with results for normal lead styphnate (Specification MIL-L-757) and dextrinated lead azide (Specification MIL-L-3055) obtained at approximately the same time and using the same apparatus and procedures.

4.2.1 Sample Preparation. Granular primary explosives shall be tested in the loose, as prepared condition, after drying to constant weight at 65°C. Primary compositions with binders and solvents or with curing binders shall be dried, then ground in a ball mill using a dispersing fluid in which none of the ingredients including the binder are soluble, and finally heated to constant weight at 65°C.

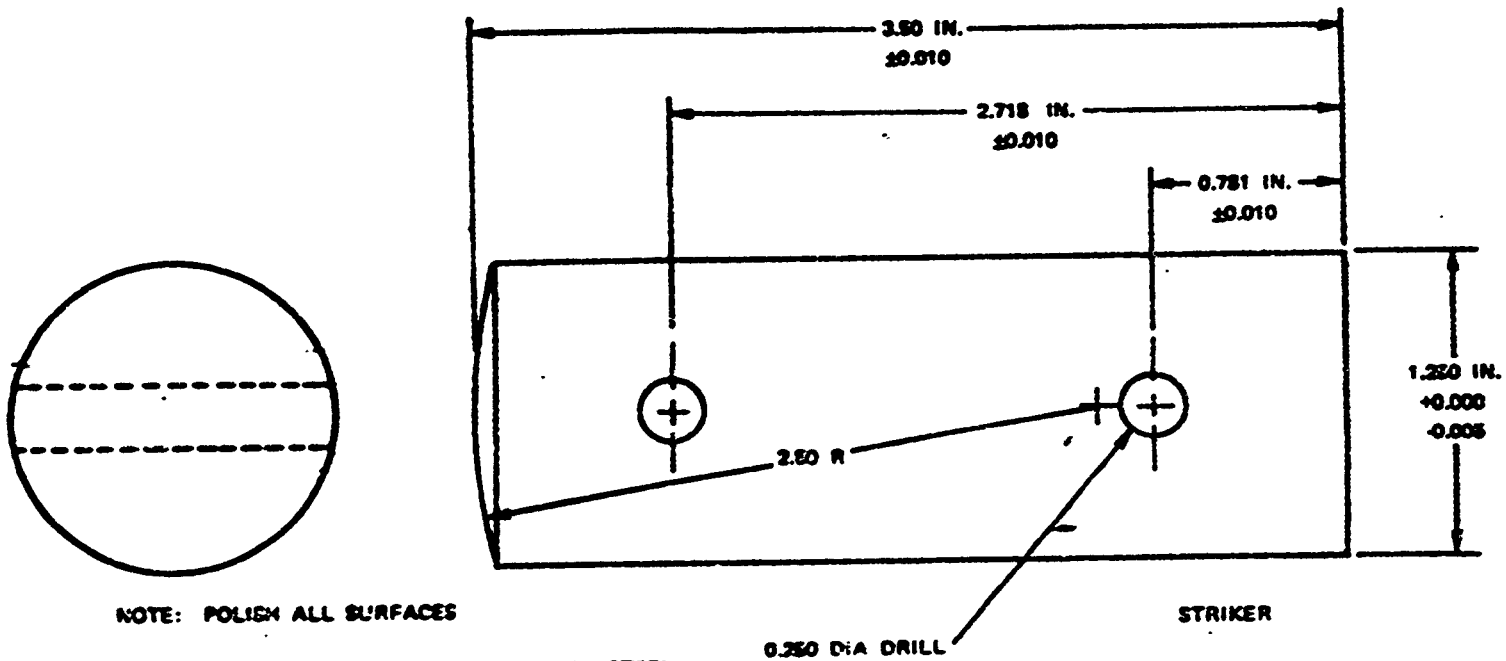
4.2.2 Test Procedure. Place a 35 ± 1 mg sample of the candidate primary explosive on the rough side of a piece of No. 05 sandpaper which is supported on the steel anvil shown in Fig. 1-2. Place the hardened steel striker, Fig. 1-3, over the sample of explosive resting on the sandpaper and anvil. Drop a 2-1/2 kilogram steel weight from a height of 50 cm in



NOTE POLISH ALL SURFACES

MATERIAL – KETOS OIL HARDENING TOOL STEEL
(CRUCIBLE STEEL CO.) HEAT TREAT
TO ROCKWELL C–60 HARDNESS

FIG. 1-2. Anvil for Impact Sensitivity Test.



NOTE: POLISH ALL SURFACES

MATERIAL – KETOS OIL HARDENING TOOL STEEL (CRUCIBLE STEEL CO.) HEAT TREAT TO ROCKWELL C-60 HARDNESS

ty Test.

FIG. 1-3. Striker for Impact Sensitivity Test.

a frictionless guided drop so that it impacts the striker centrally. Note whether the response of the explosive is positive (explosion, burning, or other evidence of reaction) or negative. If the response is positive, reduce the height of the next drop by 50%; if negative, increase the height by 100% and proceed until a region is found where a 50 trial Bruceton test can be run. The test shall be run following the procedure of AMP Report No. 101.1R, Statistical Research Group, Princeton University 1944, using logarithmic step sizes of approximately 1 standard deviation of the mean.

4.2.3 Qualification Criterion. There is no qualification criterion for this test. The test results shall be reported along with those for normal lead styphnate and dextrinated lead azide. (A normal range for these compounds shall have been obtained at the time of testing the explosive to be qualified.)

4.3 Electrostatic Sensitivity.

A dry representative sample of a candidate primary explosive shall be subjected to an electrostatic sensitivity test using the apparatus described in NAVORD Report 6632 and NOLTR 65-124 and using the procedure described in NOLTR 65-124. The test shall be run for both electrodes of metal and for the base electrode of conductive rubber. The results shall be compared with those for normal lead styphnate (MIL-L-757) and dextrinated lead azide (MIL-L-3055).

4.3.1 Sample Preparation. Granular primary explosives shall be tested in the loose, as prepared condition after drying to constant weight at 60°C. Primary compositions with binders and solvents or with curing binders shall be dried, then ground in a ball mill using a dispersing fluid in which none of the ingredients including the binder are soluble, and finally heated to constant weight at 65°C.

4.3.2 Test Procedure. Place approximately 15 mg of the explosive in the phenolic holder and position on the base electrode. Rotate the charge/discharge knob to charge the capacitor to the full 7,500 volt apparatus limit and hold in position until the voltmeter shows that the potential is reached. Rotate the charge/discharge knob to discharge the capacitor

through the sample. Using only the voltage steps given below, repeat the procedure until, for each capacitor size, the highest voltage at which twenty out of twenty samples do not fire is determined. The test shall be run for each capacitor size and for each electrode condition, i.e., base electrode metal and base electrode conductive rubber.

Voltage Steps	Capacitor Sizes
250	1 mfd
500	0.1 mfd
1,000	0.01 mfd
1,500	0.001 mfd
3,000	
4,500	
6,000	
7,500	

4.3.3 Definition of Fire. For the purpose of paragraph 4.3.2 a fire shall be defined as any audible report or noise that can be distinguished from the noise of the spark and/or any visible smoke or flame emitted from the sample.

4.3.4 Qualification Criterion. There is no qualification criterion for this test. The test results shall be reported along with those for normal lead styphnate and dextrinated lead azide obtained using the same apparatus and procedure and run at the same time.

4.3.5 Special Requirements.

4.3.5.1 Relative Humidity. The test must be run with ambient relative humidity not exceeding 40%. Humidity shall be determined by wet and dry bulb hygrometry or by instruments of equal or better accuracy and precision.

4.3.5.2 Electrode Replacement. The upper (needle) electrode shall be replaced after it has been used in ten trials, after any trial in which a fire is obtained, whenever tests of a new explosive are started, or when any other condition dictates, whichever circumstance occurs first.

4.4 Compatibility With Materials of Construction.

4.4.1 Discussion. On the surface the mandatory requirement on thermal stability is disarmingly simple. This is because a single thermal stability test will not be feasible for all primary explosives. Some primary compositions may not be amenable to any thermal stability test that does not include a performance requirement. Categorize the primary explosives on the basis of their reaction products into gassy materials and "gasless" materials. As implied, the gassy materials produce much gas on decomposition; the "gasless" materials very little gas. Each of the two categories may be further subdivided:

Gassy Materials	Examples
a. Single Compounds	Lead Styphnate, lead azide
b. Mixtures	NOL 130, NOL 60, FA 878
"Gasless" Materials	**Examples**
a. Single Compounds	Silver acetylide
b. Mixtures	Zirconium/potassium perchlorate, A-1A

In general, the gassy materials are used in detonating systems; the gasless materials in delay trains, explosive switches, igniters, and some 1 amp/1 watt no fire devices.

Testing for the gassy materials usually is not difficult. A vacuum thermal stability test can be run on the compound or mixture. It should be noted, however, that running the test on individual ingredients of a mixture can be misleading if results are improperly interpreted. For example, NOL 130 and NOL 60 compositions are thermally stable, but tetracene, a constituent of both mixes, is itself not thermally stable.

The "gasless" materials pose quite a problem. It is likely that a performance test will be necessary for them. A single performance test may not suffice because different compositions may be compounded for quite different uses, i.e., stab action or hot wire action. Testing for some other property may not be applicable.

4.4.2 Gassy Materials. Mix proposed explosive and material and subject to the 100°C VTS test given in paragraph 4.1.

4.4.3 Gasless Materials. Mix proposed explosive and material, subject to 100°C for 48 hours and conduct appropriate chemical analysis and performance tests.

5. DESIRABLE BACKGROUND INFORMATION

In addition to mandatory requirements, all available background information should be obtained on a new primary explosive prior to use. This type of information includes the following:

5.1 Detonation Velocity.

Assemble the test equipment as shown in Fig. 1-4 and 1-5. Press the primary explosive so that it reaches a uniform density of 90-95% theoretical maximum density (TMD). Conduct five identical tests and record the detonation velocity in meters/second and the measured density.

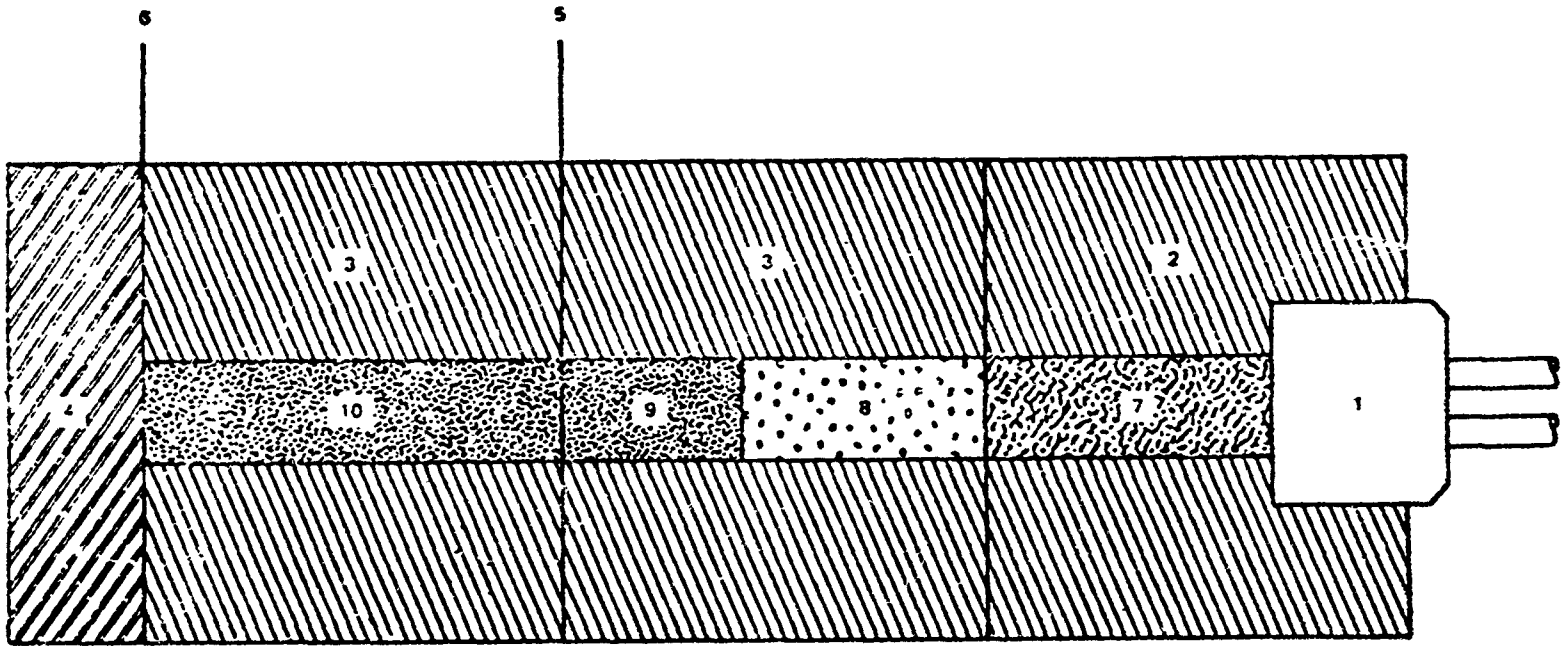
5.2 Density.

Use any standard method of determining density on three samples pressed at 20,000 ± 500 psi.

5.3 Priming Ability.

Load 200 mg of RDX in the base of the cup as shown in Fig. 1-6 and press to 10,000 psi. Place 100 mg of the proposed priming composition loosely on top. Position safety fuze as shown in Fig. 1-6 on top of primary composition; use sufficient fuze (120 sec/yd) to retire to a safe position. Light the safety fuze with a match and remain in a safe position until after explosion. Measure the depth of the dent in the steel plate. If it exceeds ____ inches*, reduce the primary charge by 15 mg and repeat test. If it is less than ___ inches*, increase the primary charge by 15 mg and repeat test. Repeat this procedure increasing

*Values to be determined.



1. MK 114 ELECTRIC PRIMER
2. BRASS CYLINDER – 1.0 IN. OD X 0.2 IN. ID, PRIMER RECESS 1.0 INCH LONG.
3. BRASS CYLINDER – 1.0 IN. OD X 0.2 IN. ID X 1.0 IN. LONG
4. CIRCULAR 1020 STEEL BLOCK – 1.0 IN. DIAMETER X 0.5 IN. THICK, ROCKWELL 70–85
5. START PROBE TO HEWLETT – PACKARD TIMER, MODEL 5275A
6. TIMER STOP PROBE
7. LEAD AZIDE PRESSED TO 10,000 PSI AT LEAST 0.5 IN. LONG
8. RDX PRESSED TO 10,000 PSI
9. PRIMARY EXPLOSIVE BEING EVALUATED, PRESSED TO 10,000 PSI AT LEAST 0.4 IN. LONG.
10. PRIMARY EXPLOSIVE BEING EVALUATED, AT 80–85% TMD

FIG. 1-4. Detonation Velocity Test.

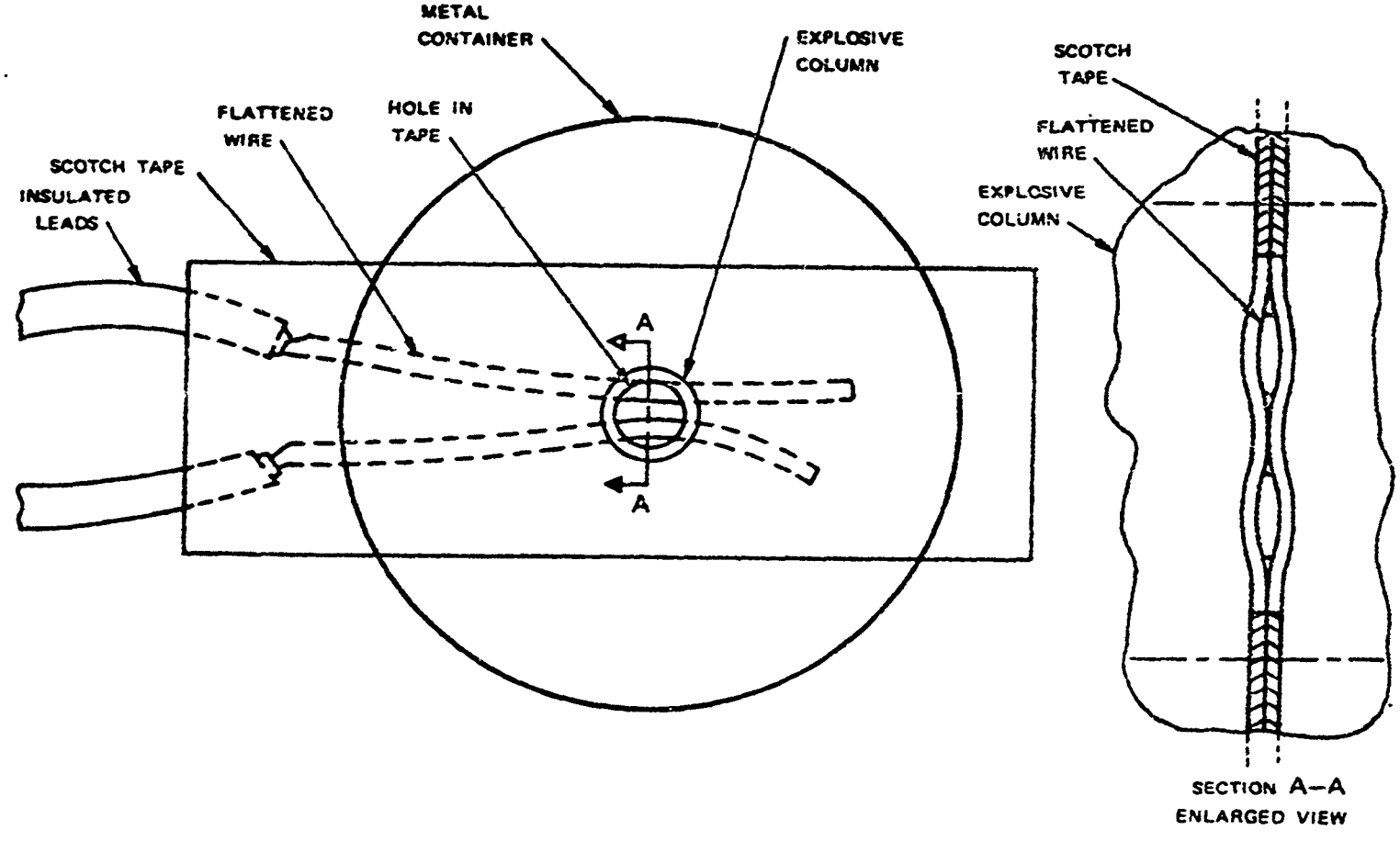
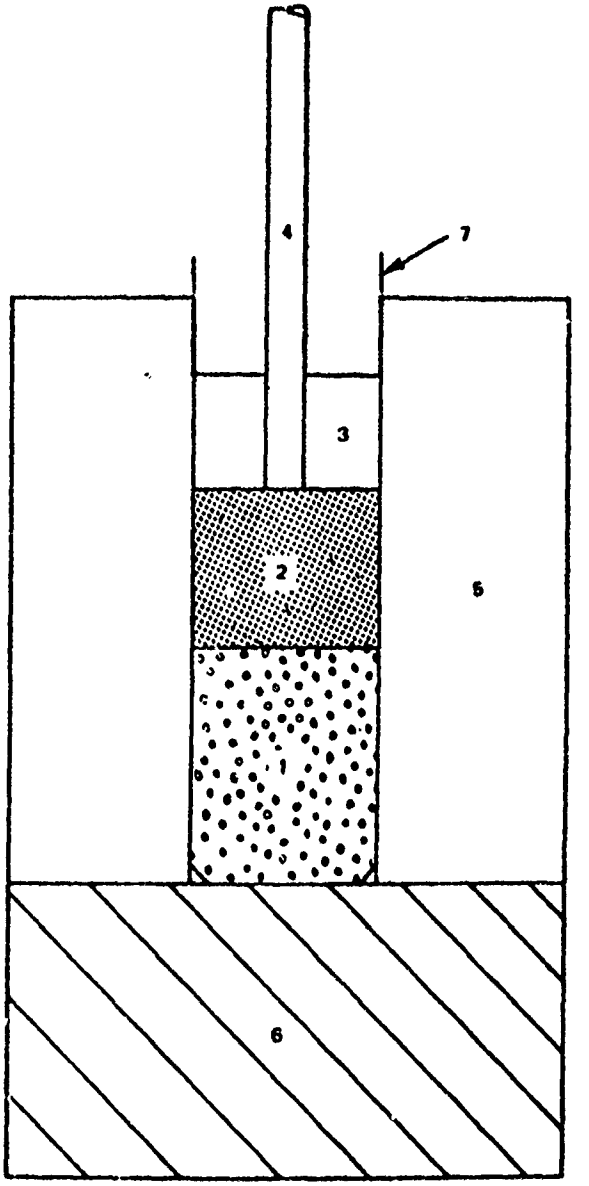


FIG. 1-5. Probe Construction.

OD 44811



1. 200 mg RDX PRESSED AT 10,000 PSI
2. PRIMARY EXPLOSIVE BEING EVALUATED, LOOSE
3. PLASTIC (OR WOOD) HOLDER FOR SAFETY FUZE
4. SAFETY FUZE, 120 SEC/YD
5. PMMA HOLDER, 1.0 IN. OD X 0.285 IN. ID
6. 1020 STEEL PLATE, 1.0 IN. DIAMETER X 0.5 IN. THICK, ROCKWELL B 70-95
7. GILDING METAL CUP, 0.275 IN. OD X 0.26 IN. ID X 1.5 IN. LONG

FIG. 1-6. Typical Arrangement for Priming Ability Tests.

or decreasing each succeeding primary charge by 15 mg until a legitimate 30 trial Bruceton run is obtained. Calculate the 50% priming charge weight and standard deviation.

5.4 Dent Output.

Make five test items as described in paragraph 5.3, replacing all explosive charges (both RDX and primary) with 300 mg of the primary explosive only, pressed at 10,000 psi. Initiate with safety fuze and measure dent depth in steel plate. Calculate and record the average of 5 tests.

5.5 Dead Pressing Susceptibility.

Repeat paragraph 5.4 increasing the pressure loading as follows: 5 at 20,000 psi, 5 at 30,000 psi, 5 at 40,000 psi, etc., until the dent value falls by at least 50% or 100,000 psi is reached, whichever occurs first.

5.6 Solubility in Water.

Use any standard method to determine solubility in water.

5.7 Hot Wire Initiability.

Bridge 60 P-12 plugs with a 0.0005 nichrome wire. Attach a charge holder with a 0.1-inch-diameter charge hole and press in 20 mg of the primary explosive at 5,000 psi. Fire 30 plugs in a continuous constant current Bruceton test (current applied for 10 seconds, current constant to ± 2%) and 30 in a capacitor discharge Bruceton test using a 0.1 mfd capacitor and 0.03 log unit voltage steps. Repeat using 60 plugs with 0.001 diameter nichrome wire. Record the number of detonations for each test condition and calculate the means and standard deviations.

5.8 Stab Initiability.

Load 50 Mk 102 Mod 1 primer cups with the primary explosive pressed at 20,000 psi. Determine sensitivity using the Bruceton method and the Mk 136 test set. Repeat with explosive loaded at 80,000 psi.

5.9 Differential Thermal Analysis (DTA).

Run a standard DTA using a heating rate of 25°C/minute. Report the curve obtained showing temperatures of all exotherms and endotherms together with sample size and identification.

5.10 Cook-off Temperature.

Using a standard melting point bar, determine the lowest temperature at which approximately 5 mg samples of the primary explosive flash-off.

5.11 Friction Sensitivity.

To be determined.

5.12 Suggested Loading Procedure.

Suggested loading procedures for the explosive being qualified will be prepared and submitted to the Naval Ordnance Systems Command for approval.

Primary explosives are by their nature, sensitive materials which may explode in a system outside of the usual functioning mode. Hence out-of-line or interrupter systems are used to provide for adequate safety. Therefore, final qualification of components containing primary explosives will be made on the basis of their behavior in the system of which they are a part. Usually, however, primary explosives containing components are subjected to the appropriate tests of MIL-STD-331; these include jolt, jumble, transportation vibration, 40-foot drop, and the temperature-humidity cycle.

It is necessary, however, for explosives qualifying under this publication to contain in their procurement specifications a sufficient number of the tests described in Chapters I and II to assure continued quality control of any of the properties described. The procuring activity may invoke the requirements of this document at their discretion to ascertain if the explosive, as procured, still qualifies.

The quality control provisions of the procurement specification must also be reviewed to determine whether they adequately define the material evaluated for qualification and assure that the stability and sensitivity characteristics of the explosive will continue to meet the criteria of this document.

There are no other requirements for the primary explosive per se for final qualification.

CONTENTS

1. SCOPE

1.1 Purpose. This chapter establishes criteria for the selection and acceptance of explosives for use in fuze components so located that their detonation would normally be communicated to the main explosive charge of a fuzed weapon when the fuze is in the armed or unarmed condition. Explosives used in leads, relays, detonating cord, and boosters are included when so located with respect to the interrupter.

1.2 Applicability. This document is to be applied as a qualification standard for booster explosives and not as a procurement or quality control standard. It is necessary, however, that explosives qualifying under this document for the applications of paragraph 1.1, contain in their procurement specifications sufficient tests described herein to assure continued control of the properties which this document is designed to measure. When such tests are not included, the requirements of this document, at the discretion of the procuring activity, may be invoked to demonstrate that the explosive as procured still qualifies.

2. APPLICABLE DOCUMENTS

2.1 Specifications and Standards. The following documents of the latest issue form a part of these requirements.

SPECIFICATIONS - FEDERAL

U-T-106	Tape, Pressure-Sensitive Adhesive, Paper, Drafting.
QQ-A-250/1C	Aluminum Alloy 1100, Plate and Sheet.
TT-P-320a	Pigment, Aluminum, Powder and Paste, for Paint.
QQB-326	Brass.
QQ-S-698	Steel, Sheet and Strip, Low Carbon.

SPECIFICATIONS - MILITARY

JAN-P-408	Pentolite 50/50.
MIL-A-512A	Aluminum Powder.
MIL-L-3055	Dextrinated Lead Azide.

MIL-P-387A	PETN.
MIL-R-398	RDX.
MIL-T-00339A	Tetryl.

STANDARDS - MILITARY

MIL-STD-320	Terminology, Dimensions, and Materials of Explosive Components for use in Fuzes.
MIL-STD-444	Nomenclature and Definitions in the Ammunition Area.
MIL-STD-1314	Safety Precautions for Explosive Loaded Items.
MIL-STD-1316A	Fuze Design Safety, Criteria for

2.2 Drawings.

CHIEF OF NAVAL MATERIALS

LD 486247	Detonator, Electric, Mk 79 Mod 0.
LD 533566	Detonator, Electric, Mk 86 Mod 0.
457454	Plug Assembly.
652246	Spacer.
2426912	Explosive Properties Assembly.
2426913	Donor Assembly.
2426914	Accepter Assembly.
2426915	Body.
PL/DL 618104	Static Discharge Test Set.

BUREAU OF NAVAL WEAPONS

457454	Plug Subassembly.
652246	Spacer.

2.3 Reports.

Naval Ordnance Laboratory. Standardization of the Small Scale Gap Test Used to Measure the Sensitivity of Explosives by, J. N. Ayres. White Oak, Md., 16 January 1961. (NAVWEPS Report 7342.)

Naval Ordnance Laboratory. VARICOMP: A Method for Determining Detonation - Transfer Probabilities, by J. N. Ayres, L. D. Hampton, et al. White Oak, Md., 30 June 1961. (NAVWEPS Report 7411.)

Naval Ordnance Laboratory. The Development of Impact Sensitivity Tests at the Explosives Research Laboratories, Bruceton, Penn. During the Years 1941-1945. White Oak, Md., 6 March 1956. (NAVORD Report 4236, CONFIDENTIAL.)

3. TERMS AND DEFINITIONS

3.1 Terminology. Standardized terminology is used in this document in accordance with the definitions of MIL-STD-444 and, more particularly, MIL-STD-320.

3.2 Definitions. The following specialized terms and definitions are applicable to the requirements of this document.

3.2.1 Booster Explosive. As used herein, a "Booster Explosive" is defined as an explosive acceptable for fuze components whose detonation would normally be communicated to the main charge explosive of a fuzed weapon when the fuze is in either armed or an unarmed condition. This will include explosives used in leads, relays, detonating cord, and other components used on the warhead side of the interrupter.

3.2.2 Explosive (Material). The term explosive or explosive material, referring to a compound or composition being investigated for qualification in accordance with this document, denotes a specific composition with ranges specified which have been covered by the safety tests of this document. Whenever changes in particle size, purity, process of manufacture, grade, class, or any other modification is made, it shall be established that safety is not compromised and determination of whether the composition becomes a new composition requiring a complete rerun of the qualification will be made jointly by the qualifying group with the approving Department of Defense office from the cognizant service.

3.2.3 Candidate Explosive. As used herein, the term "candidate explosive" is any explosive material being evaluated in accordance with this document.

3.2.4 Test. As used herein, the term "test" is the complete series of trials or replicates specified.

3.2.5 Trial. The term "trial" means the application of a stimulus to a single specimen of explosive.

3.2.6 Representative Sample. Sampling procedures may be varied to accommodate circumstances. However, where feasible, part of each representative sample shall be drawn from each container and from various locations within each container. The sample shall not be blended before use in tests.

3.2.7 Sub-Sample. Where part of each sample, as specified above, is drawn from each container and/or from various locations within each container, each such part is considered to be a "sub-sample".

4. GENERAL REQUIREMENTS

4.1 Basic. All explosives used in fuzes in direct communication with main explosive charges shall have met all of the mandatory requirements given in Section 5. Each explosive material, as defined in paragraph 3.2.2, shall meet those requirements.

4.2 New Compositions. In addition to passing the tests prescribed in the mandatory requirements, each compound or mixture proposed for use as a booster explosive shall be studied for the possibility of reactions with containers or contaminants or phase transitions under anticipated conditions of use. Experiments shall be performed to determine the probability of such changes and their effect upon sensitivity as determined by tests described in Section 5.

4.3 Explosive Description and Analysis. A description of what constitutes the explosive (including its composition analysis) shall be presented when applying for an interim qualification. The explosive shall be adequately defined and shall have met the requirements of this chapter.

4.4 Specimens, General Requirements. The following paragraphs and the more specific requirements for specimen preparation for specific tests under Section 5 are directed toward the preparation of specimens of each candidate explosive in a physical or chemical state similar (as is practical and compatible with test procedures) to the physical and chemical state in which the candidate explosive is to be used. Where within the latitude of the requirements as given it is necessary to exercise judgment regarding specimen preparation, this objective shall form the basis of such judgment.

4.4.1 Sub-Samples. To the extent that it is practical and feasible, sub-samples shall be kept separate, and equal numbers of specimens for each test described under Mandatory Requirements shall be drawn from each sub-sample of a candidate explosive.

4.4.2 Granular Explosives. For each test described under Mandatory Requirements, a procedure is described for the preparation of specimens from granular explosives. These procedures are applicable to pure crystalline explosives and granular explosive mixtures, including plastic bonded explosives, which are normally formed by pressing at temperatures below the melting point of the binder and at which the binder does not undergo a chemical change (such as curing) as part of the fabrication process.

4.4.3 Cast, Molded, and Extruded Explosives. For each of the tests described in the Mandatory Requirements, the dimensions of the specimen required for each trial are given either in the test or a referenced drawing where necessary. Where the dimensions of a specimen to be used in a specific test are compatible with fabrication procedures for which the candidate explosive is intended, such procedures shall be used in specimen preparation. Where intended fabrication procedures are only feasible for charges very much larger than the specimens specified herein, these procedures shall be used to form billets of the candidate explosive from which test specimens can then be machined. Specimens for each test

described shall be made from material taken at each of several locations with respect to the principal dimensions of the billets from which they are machined.

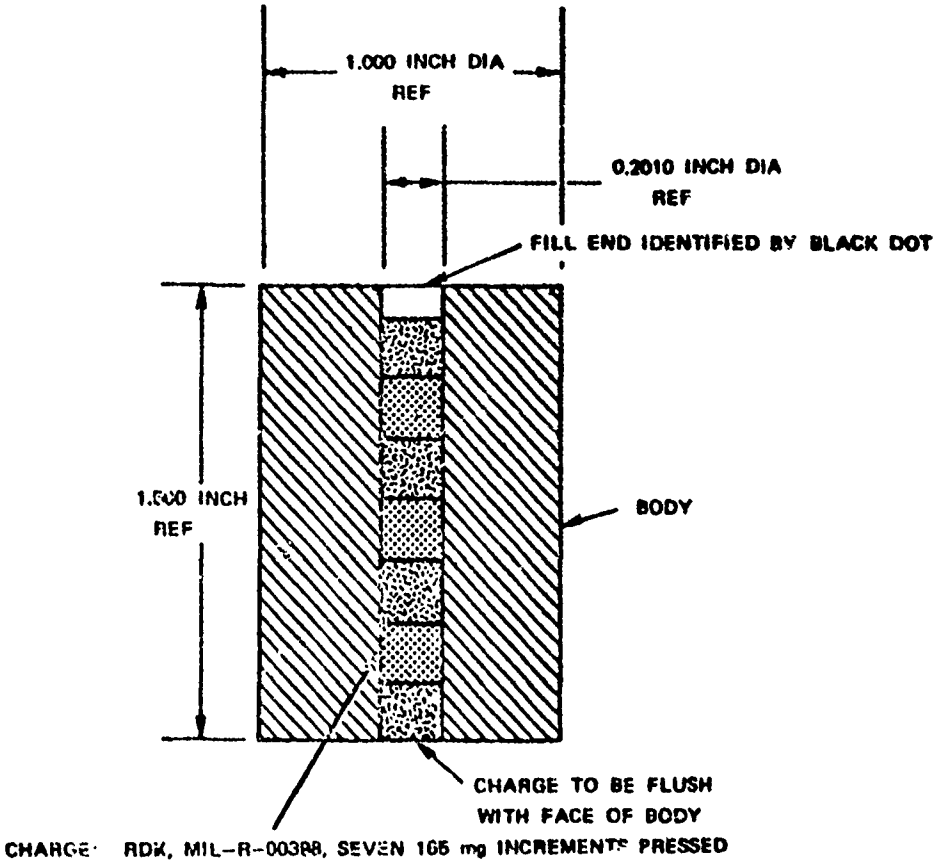
4.4.3.1 Other Sampling Requirements. When billets are machined, the uncontaminated chips, shavings, or dust resulting can be saved and used as specimens in tests such as the vacuum stability test (paragraph 5.4) and the electrostatic sensitivity test (paragraph 5.7) in which the tests are performed on loose powder, and hot wire ignition test (paragraph 5.5) in which a finely divided powder is used. In general, except as noted in the Mandatory Requirements, materials to be used in these tests shall be used in the "as received" state except for drying. However, explosives which have thermosetting or other binders which undergo chemical changes in the process of "curing" should be cured before testing. In tests where loose powders are used, particle size shall be reduced to the point where all material passes through a U. S. Standard No. 12 screen. Such screening shall not result in separation or loss of material too coarse to pass the screen.

5. MANDATORY REQUIREMENTS

5.1 Small Scale Gap Test (SSGT).

A representative sample of the proposed new booster explosive shall be subjected to the standardized SSGT as described in NAVWEPS Report 7342 and the following paragraphs.

5.1.1 Loading and Calibration of Donor Assemblies. Twenty-five donor assemblies shall be prepared in accordance with Fig. 3-1 (Drawing 2426913). Five of these donors shall be selected at random, assembled in the test fixture shown in Fig. 3-2, and fired againt the block by initiation of the detonator with a 50 volts DC (minimum) 20 amperes (minimum) power supply. To be acceptable for use in the sensitivity test, the average depth of dent produced in the block by the five representative donors must be between 60 and 65 mils and the standard deviation must not exceed 4.0 mils. Each block shall be used only once and the measurement of the indentation depth shall be made in accordance with paragraph 5.1.6.



CHARGE: RDX, MIL-R-00398, SEVEN 165 mg INCREMENTS PRESSED AT 10,000 PSI. MOISTURE CONTENT AT TIME OF LOADING NOT TO EXCEED 0.3%. A MINIMUM OF 4 HOURS DRYING TIME AT 50° C UNDER 28.5 INCH MERCURY VACUUM JUST PRIOR TO LOADING.

FIG. 3-1. Donor Assemblies.

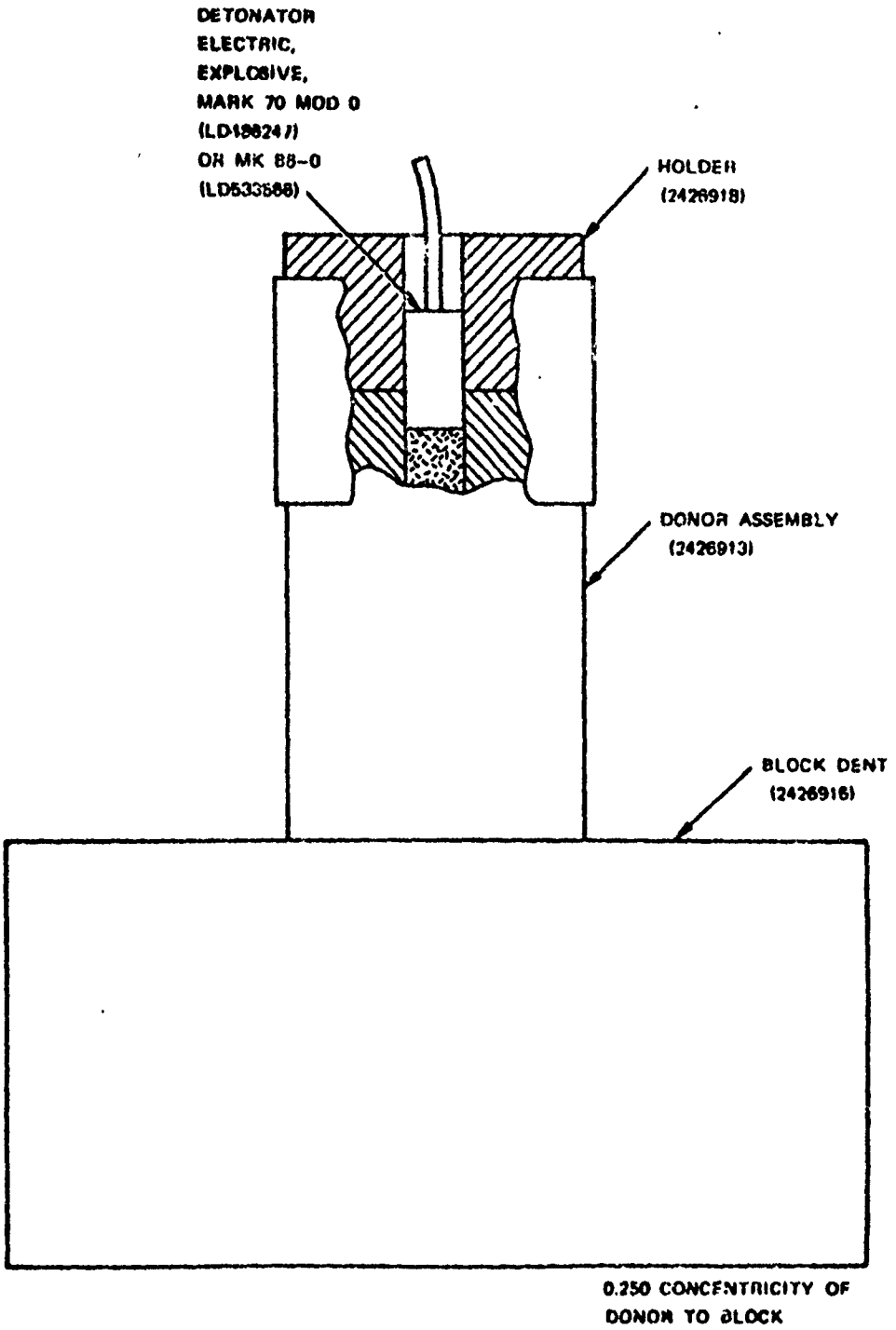


FIG. 3-2. Small Scale Gap Test Arrangement for Testing Donors.

5.1.2 Preparation of Acceptor Specimens (Granular Explosives). The explosive shall be loaded in eight equal weight increments at 16,000 ± 1,000 psi. The first trial loading shall be with increment weights in milligrams of 90 times the theoretical specific gravity of the explosive. The acceptor body (Fig. 3-3) shall be weighed before and after loading. If all eight increments fit in the acceptor body with room to spare, measure the remaining unloaded column height and adjust the weight of each increment to meet the tolerance shown in Fig. 3-3 (Drawing 2426914). Load another test body to assure that the drawing tolerance has been met. When the adjustment is satisfactory, load the acceptor bodies to form a total of 20 acceptors meeting the tolerance shown in Fig. 3-3. The acceptors shall be weighed before and after loading and each individual charge density determined and accurately reported to three decimal places. If in loading the first test body all eight increments do not fit into the acceptor body, adjust the individual increment weight based on the actual weight of explosive contained in the body and proceed to adjust and load until 20 acceptors meeting the tolerance shown in Fig. 3-3 are obtained. Acceptors shall be weighed before and after loading, and each individual charge density determined and accurately reported to three decimal places.

5.1.3 Preparation of Acceptor Specimens (Cast, Molded, and Extruded Explosives). The acceptor specimens of case, molded, and curing extruded explosives shall be prepared in accordance with paragraph 4.4.3. Where mechanical properties of the explosive make it possible rods shall be made $0.201\ ^{+0.0000}_{-0.0005}$ inch in diameter by $1.520\ ^{+0.000}_{-0.010}$ inches long. Materials which are too fragile to be conveniently made into specimens of these dimensions, may be made into shorter pellets which can be stacked end to end to result in a composite specimen of these dimensions. (For extrudable non-curing materials the explosive may be extruded directly into the acceptor and trimmed flush on each end of the acceptor body.) Each specimen shall be inserted in a body as shown in Fig. 3-4 (Drawing 2426915) after which the specimen shall be trimmed to a length, so that

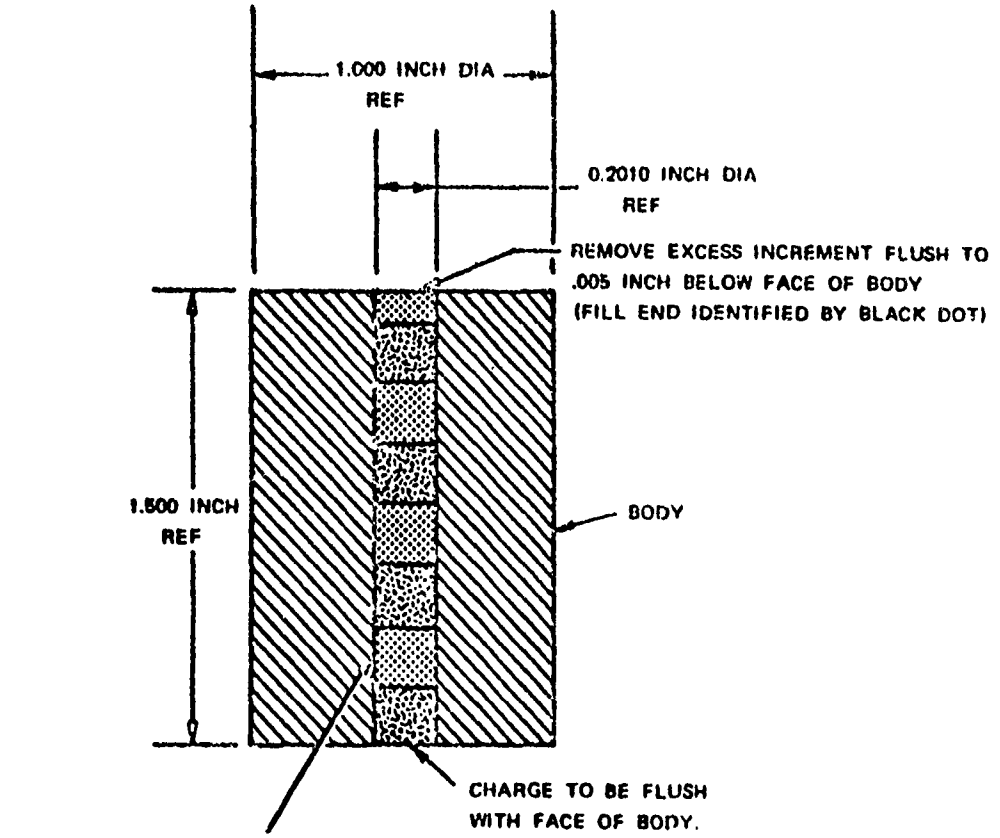


FIG. 3-3. Acceptor Assembly.

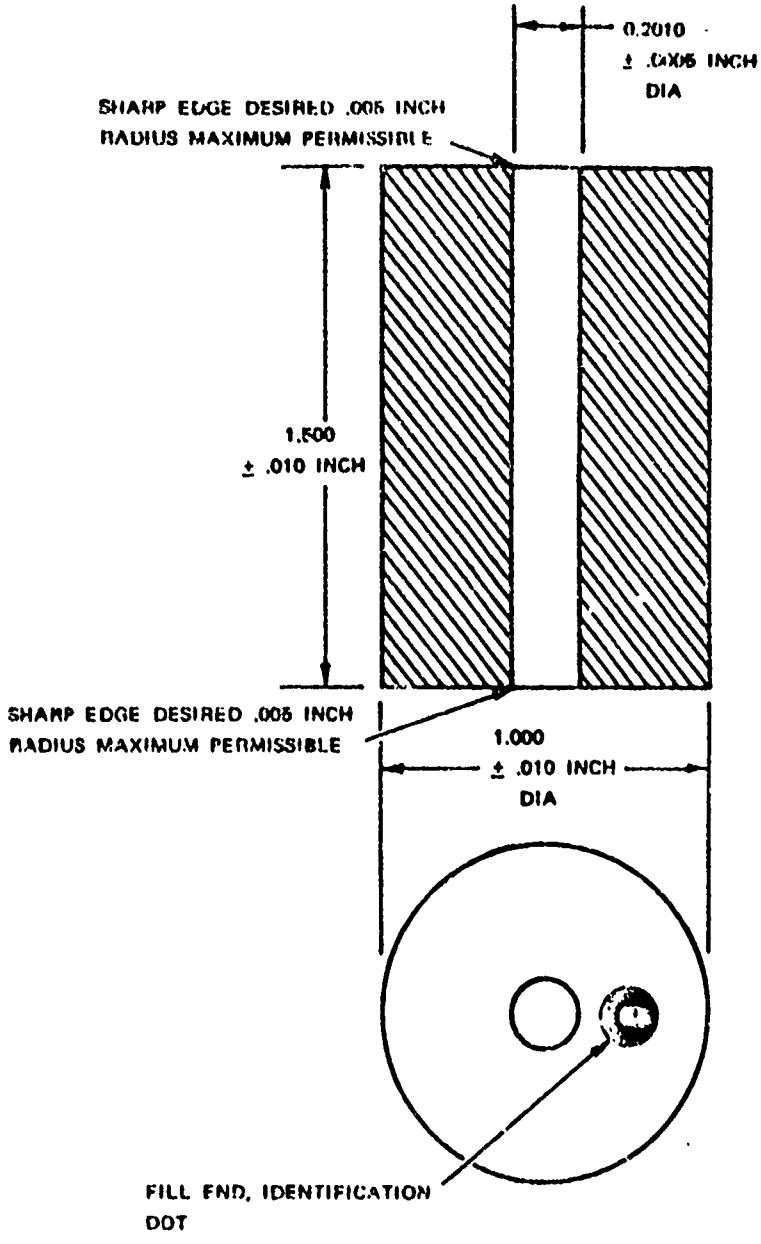

0.2010
± .0005 INCH
DIA
SHARP EDGE DESIRED .005 INCH
RADIUS MAXIMUM PERMISSIBLE
1.500
± .010 INCH
SHARP EDGE DESIRED .005 INCH
RADIUS MAXIMUM PERMISSIBLE
1.000
± .010 INCH
DIA
FILL END, IDENTIFICATION
DOT

FIG. 3-4. Body.

it is flush with the body at both ends, by a method appropriate to the specific material being tested. Before insertion into the body, each acceptor specimen shall be accurately weighed and its diameter and length accurately measured. These measuremens shall be used to accurately calculate to three decimal places the charge density for each acceptor. These densities shall be reported as an adjunct of this test.

5.1.4 Small Scale Gap Test Assemblies. Twenty explosive properties assemblies shall be prepared in accordance with Drawing 2426912 (except a Mk 86 Mod 0 Detonator may be used instead of a Mk 70 Mod 0 Detonator) from a random selection of the acceptable donors prepared in accordance with paragraph 5.1.1 and the acceptors prepared in accordance with paragraph 5.1.2 or 5.1.3. The concentricity of the acceptor to the dent block shall be within 0.250 inch and the concentricity of the external surfaces of the donor, attenuator, and acceptor shall be within 0.005 inch.

5.1.5 Test Procedure. Twenty assemblies shall be fired using 4.0 decibang (see NAVWEPS Report 7411) attenuators. The dents produced in the witness blocks shall be measured in accordance with paragraph 5.1.6.

5.1.6 Measurement of Indentation Depth. Depth of indentation made in the block by the explosion of the donor or acceptor as applicable, shall be measured with a dial indicator capable of measuring 0.001 inch units and accurate to 0.005 inch or better. The point of the dial indicator probe shall have an approximate 30 degree included angle and the end of the point shall have a radius of 0.025 ± 0.002 inch. Before measuring the depth of indentation in the block, remove any foreign material, such as deposits, from the dent. Zero the indicator with the point of the probe in the deepest part of the dent. Take the readings at four points near the periphery of the block. These points shall be approximately 0.125 inch away from the periphery and 90 degrees apart.

5.1.7 Qualification Criterion. The candidate explosive shall be reported to have passed the Small Scale Gap Test and classified as a booster explosive as defined in 3.2.1 if there are no explosions in 20 and only 20 trials. Any reaction causing a dent of 0.002 inch or more shall be considered an explosion.

5.2 Impact Sensitivity (Small Scale Drop-Weight Test).

A representative sample of a proposed new booster explosive shall be subjected to an impact sensitivity test using ERL Type 12 tools as described in NAVORD Report 4236.

5.2.1 Specimen Preparation (Granular Materials). Granular materials as defined in paragraph 4.4.2 shall be used as received. The specimen size shall be approximately 35 ± 1 milligrams.

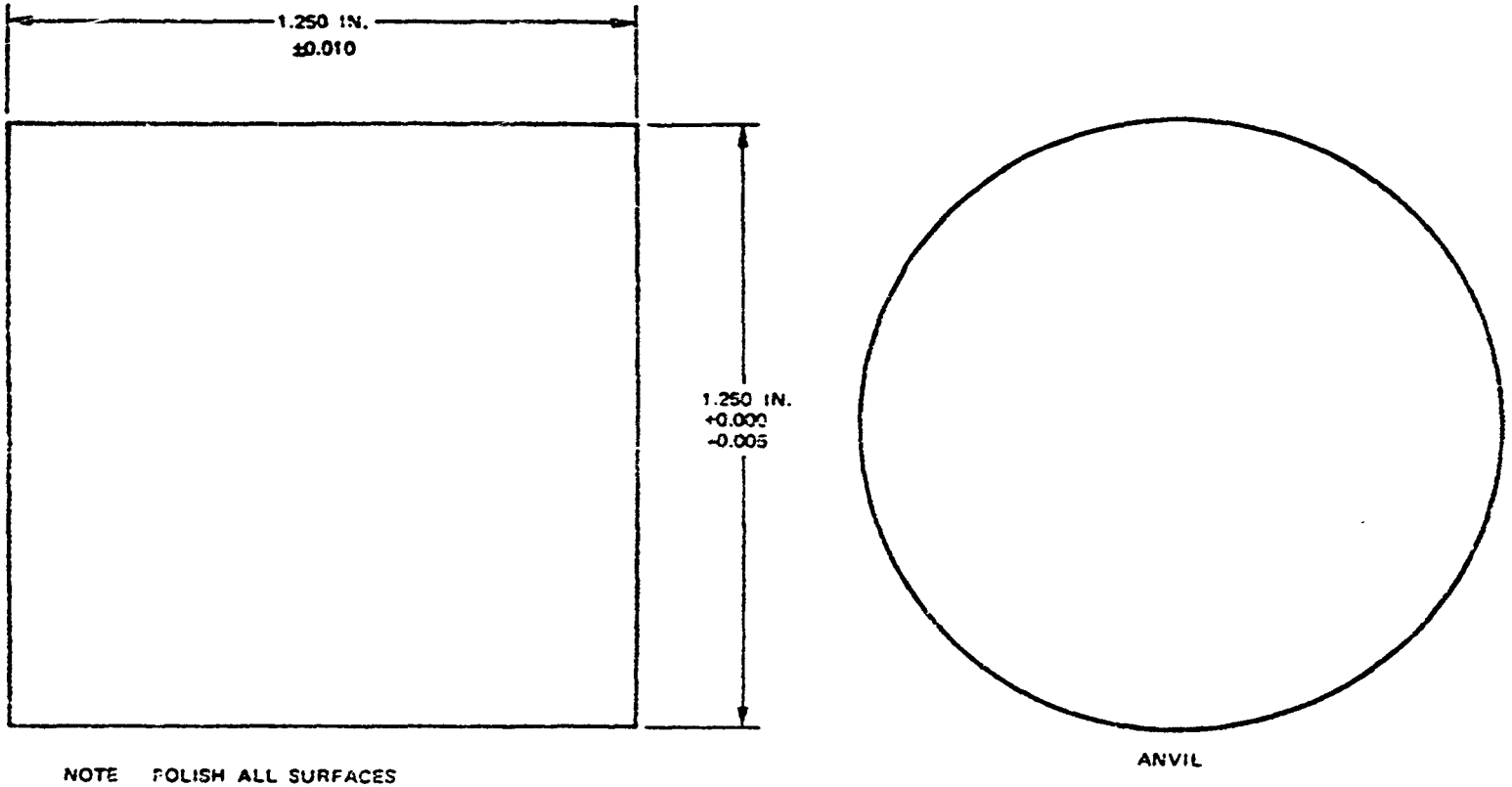
5.2.2 Specimen Preparation (Cast, Molded, and Extruded Explosives). Samples of cast, molded, or extruded explosives shall be prepared in accordance with paragraph 4.4.3. Each specimen shall be a pellet not less than 0.25 inch in diameter and 0.025 $^{+0.000}_{-0.010}$ inch thick. When testing non-curing extrudable explosives, this size pellet should be formed directly on a piece of sandpaper as described in paragraph 5.2.3 below.

5.2.3 Test Procedure. Place a specimen of the candidate explosive prepared in accordance with paragraph 5.2.1 or 5.2.2 (taken from the sample prepared in paragraph 5.1.2) on the rough side of a piece of No. 05 sandpaper which is supported on the steel anvil shown in Fig. 3-5. Place the hardened steel striker shown in Fig. 3-6 over the sample of explosive resting on the sandpaper and anvil. Drop a 2-1/2 kilogram steel weight from a height of 12 centimeters in a frictionless guided drop so that it impacts the striker centrally.

5.2.4 Qualification Criterion. The candidate explosive shall be reported to have met the impact sensitivity test and to be acceptable as a booster explosive as defined in paragraph 3.2.1 if there are no explosions, burning, or other positive evidence of reaction in 20 of only 20 trials.

5.3 Impact Vulnerability ("Flying Plate" Test).

5.3.1 Experimental Conditions. Impact vulnerability tests for this requirement shall be performed using the arrangement shown in Fig. 3-7 and the following experimental conditions.



NOTE POLISH ALL SURFACES

MATERIAL – KETOS OIL HARDENING TOOL STEEL
(CRUCIBLE STEEL CO.) HEAT TREAT
TO ROCKWELL C-60 HARDNESS

FIG. 3-5. Anvil for Impact Sensitivity Test.

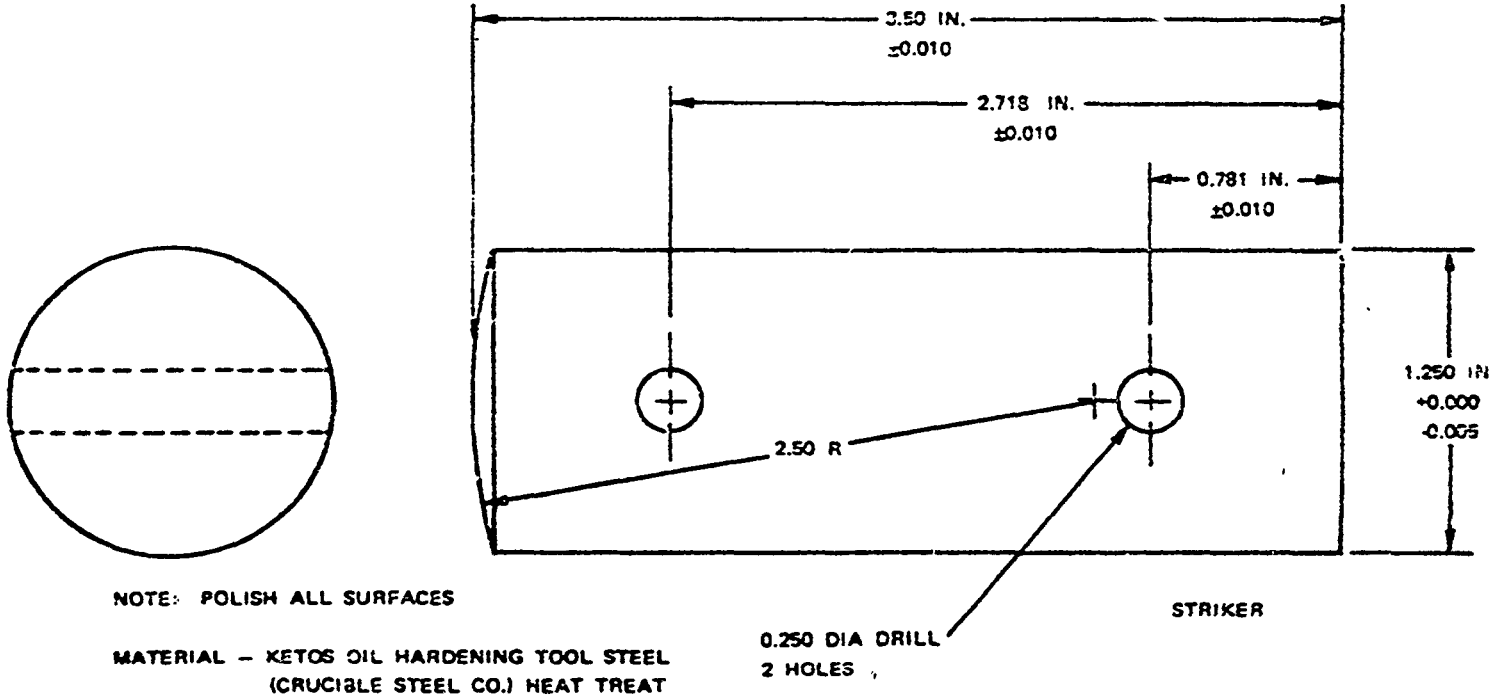


FIG. 3-6. Striker for Impact Sensitivity Test.

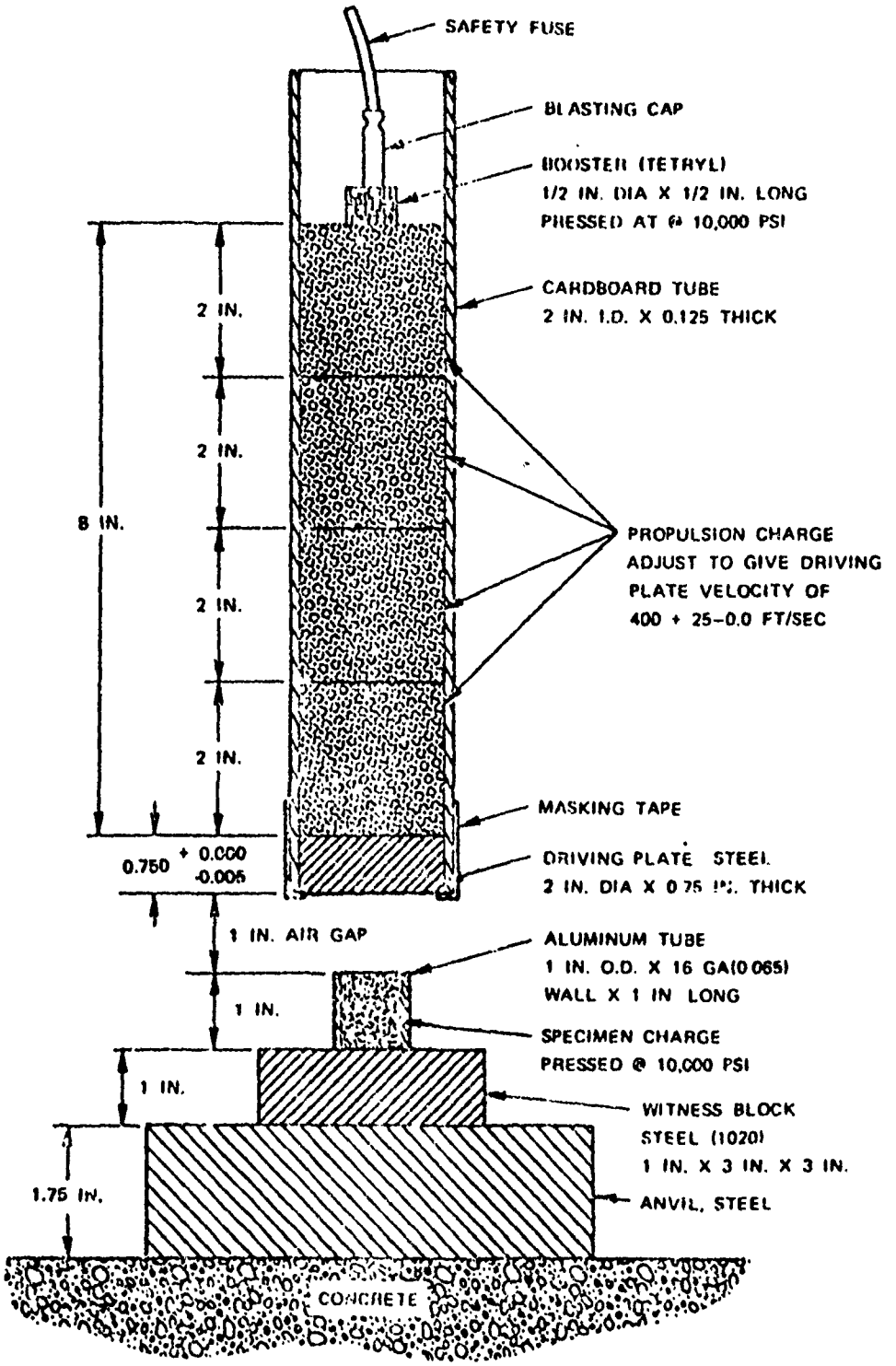


FIG. 3-7. Impact Vulnerability Test Arrangement.

5.3.1.1 Specimen Dimensions. The specimen used for each trial in an impact vulnerability test shall consist of one cylindrical pellet 7/8 inch in diameter and 1 inch long, loaded directly into an aluminum tube 1.00 inch OD x 0.870 inch ID.

5.3.1.2 Specimen Preparation (Granular Explosives). The pellets shall be prepared by pressing at 16,000 ± 1,000 pounds per square inch.

5.3.1.3 Specimen Preparation (Cast, Molded, and Extruded Explosives). Specimens of cast, molded, or extruded explosives shall be prepared in accordance with paragraph 4.4.3. (Extrudable non-curing explosives may be extruded directly into the aluminum tube.) Each specimen shall be a pellet $0.865\ ^{+0.000}_{-0.005}$ inch in diameter and $1.000\ ^{+0.000}_{-0.005}$ inch long. The specimen shall be inserted in the aluminum tube as shown in Fig. 3-7.

5.3.1.4 Driving Plate. The driving plate used in the impact vulnerability tests for this requirement shall be AISI E6150 steel, heat treated to a hardness of 28-31 Rockwell C. The driving plate shall have a diameter of 2.000 inches and a thickness of $0.750\ ^{+0.000}_{-0.005}$ inch.

5.3.1.5 Propulsion Charge. The propulsion charge shall be sufficient to propel the driving plate at a velocity of $400\ ^{+25}_{-00}$ feet per second. In the arrangement shown in Fig. 3-7, with an explosive column 2 inches in diameter by 8 inches long, nitroguanidine loaded at 0.685 gm/cc (70.5 gm = 1,100 grains in each 2-inch increment) should give the desired result, but the velocity shall be measured in preliminary experiments. The method of velocity measurement shall be accurate to within 2 percent and may be made by any of several techniques depending upon instrumentation available. Either optical or electronic techniques are permissible. Satisfactory measurements are possible with framing and smear cameras and with oscilloscopes and interval timers. The propulsion charge shall be adjusted until five consecutive shots give velocities within the specified range. The propulsion charge density which gives this result shall be used in the test of the 20 charges of each candidate explosive.

5.3.2 Impact Vulnerability Qualification Criteria. A candidate explosive shall have passed the impact vulnerability test and be acceptable as a booster explosive as defined in paragraph 3.2.1 if there are no explosions in 20 of only 20 trials.

5.3.2.1 Criterion of an Explosion. For purposes of this specification, any reaction which causes detectable damage to the witness plate shall be considered an explosion.

5.4 Vacuum Thermal Stability Test.

A 100°C vacuum thermal stability test shall be run in triplicate on a composite sample of the proposed booster explosive. The apparatus and procedure shall be the same as given in specification JAN-P-408 (for 50/50 pentolite) and in the following paragraphs except that the test shall be run for 48 hours rather than 40 hours.

5.4.1 Calibration. Determine the volume in ml of the 15.5 cm heating tube (Fig. 3-8) by adding mercury from a buret until the tube is filled to the level at which the ground glass joint of the capillary tube will make contact with the mercury. Subtract from the indicated buret reading, the volume of explosive used in the test (5 ml). The difference shall be represented by the symbol A. Transfer 7.0 ml of mercury to the cup at the lower end of the capillary tube. Clamp the tube in an upright vertical position, and measure the height in mm of the mercury column in the capillary tube (approximately 25 mm). Measure the length in mm of each of the three parts of the capillary tube and add these values to obtain total length. From the total length subtract the height of the mercury column in the capillary tube as previously obtained. Represent this difference by the symbol B_1. From the total length subtract the height of the column of mercury in the capillary tube measured at the end of the test described in paragraph 5.4.2. Represent this difference by the symbol B. Determine the capacity of the capillary tube per unit of length as follows: Transfer an accurately weighed sample of approximately 10 grams of mercury to the cup at the lower end of the capillary tube. Manipulate the tube so that when it is horizontal mercury is contained in the continuous section of the longest part of the tube and

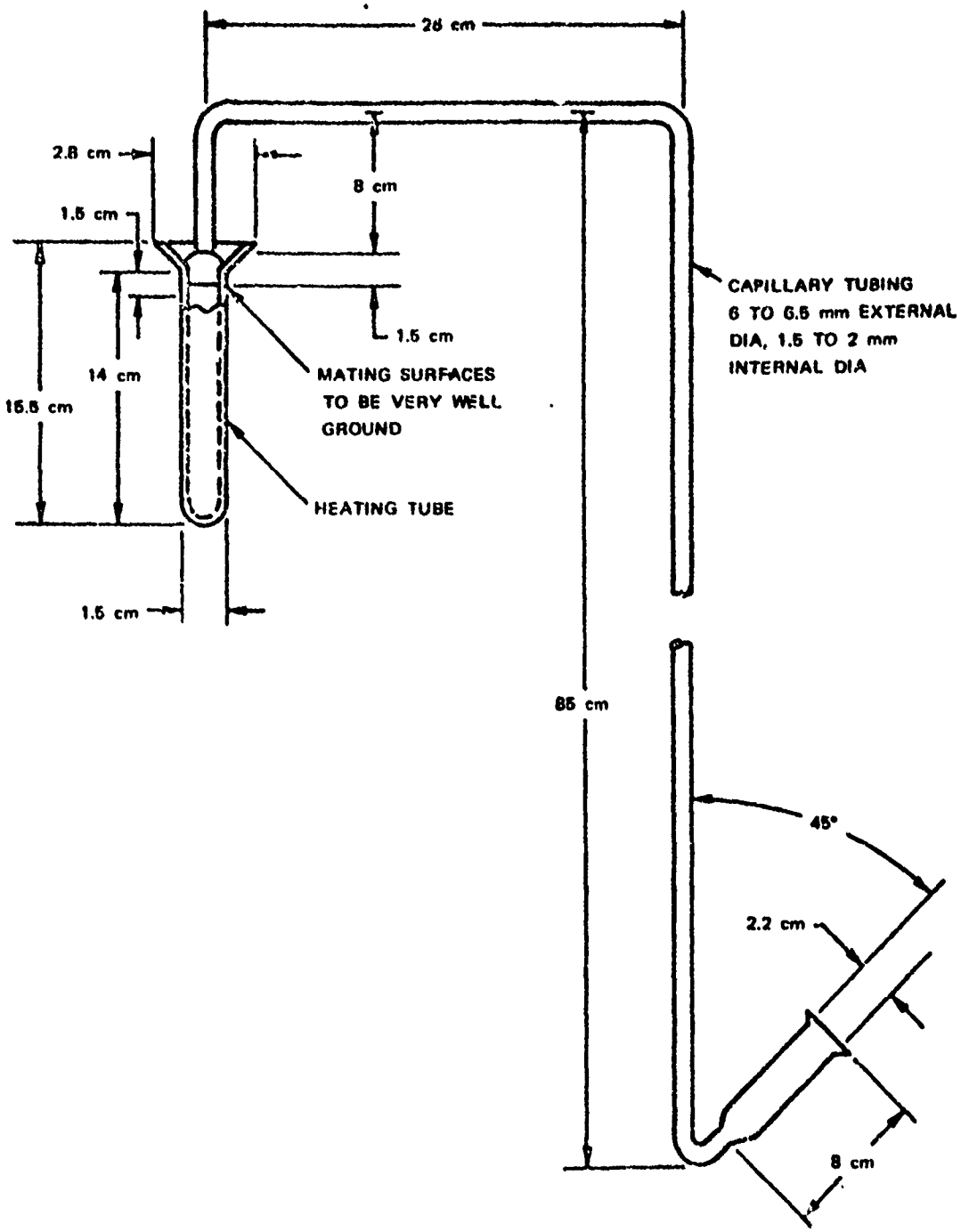


FIG. 3-8. Vacuum Thermal Stability Test.

measure the length of the mercury column. Repeat this procedure twice with the mercury in two other parts of the long section of the tube. Calculate the average of the three measured lengths of the mercury column. Represent the unit capacity in ml per mm of the capillary tubing by the symbol C. This can be obtained from the formula

$$C = \frac{W}{DL}$$

where

C = unit capacity of capillary tubing in ml per mm
W = grams of mercury
D = density of mercury at temperature of determination
L = average measured lengths of mercury column in mm.

5.4.2 Test Procedure. Transfer a 5 ± 0.05 gm sample, dried at 65°C for 2 hours, to the heating tube of the apparatus shown in Fig. 3-8. Samples shall be prepared in accordance with paragraph 4.4.2 or 4.4.3 as applicable, and selected in accordance with 4.4.1. Connect the capillary tube to the heating tube and seal the connection with 1 ml of mercury. Clamp the apparatus so that the long section of the capillary tube is in a nearly vertical position and the lower end rests on a solid support. Transfer 7.0 ml of mercury to the cup at the lower end of the capillary tube and evacuate the system until the pressure is reduced to approximately 5 mm of mercury. Disconnect the pump and measure the total vertical height of the column of mercury in the capillary tube. Measure and subtract the vertical height of the mercury in the cup. The difference shall be represented by the symbol H_1. Note the room temperature (t_1) and the barometric pressure. Subtract the value H_1 from the barometric pressure in mm. Represent this difference by the symbol P_1. Insert the heating tube in a constant temperature bath maintained at 100 ± 0.5°C. Maintain the heating tube at temperature for 48 hours. Remove the heating tube from the bath and allow it to cool to room temperature. Measure the total vertical height of the column of mercury

in the capillary tube and subtract the vertical height of the mercury in the cup. This difference shall be represented by the symbol H. Note the room temperature (t) and the barometric pressure. Subtract the value H from the barometric pressure in mm. Represent this difference by the symbol P.

5.4.3 Calculation of Gas Evolved. Calculate the volume of gas (V) in ml, at standard conditions, liberated in the test described in paragraph 5.4.2 using the value represented by the symbols described in the preceding paragraphs in the following formula:

$$V = \left[A + C\ (B-H)\ \frac{273P}{760(273 + t)}\right] - \left[A + C\ (B_1-H_1)\ \frac{273P_1}{760(273 + t_1)}\right]$$

5.4.4 Qualification Criterion. The volume of gas evolved as calculated under paragraph 5.4.3 shall be divided by the weight of the sample. This figure yields the ml of gas evolved per gm per 48 hours. To be acceptable as a booster explosive as defined in paragraph 3.2.1, none of the triplicate samples shall yield a value of more than 2.0 ml gas/gm/48 hours.

5.5 Hot Wire Ignition Test.

A representative sample of a proposed new booster explosive shall be subjected to the hot wire ignition test as detailed below.

5.5.1 Explosive Material. The explosive material particle size for this test must be small compared to the diameter of the ignition wire. Therefore, only explosive passing through a 325 mesh screen shall be used. (Except for extrudable non-curing explosives which shall be extruded directly into the charge holder and onto the bridgewire.) If a minimum of 90% of the explosive as submitted does not pass through a 325 mesh screen, a representative sample shall be taken and milled. Milling should be conducted under a noncombustible wetting agent that will neither appreciably dissolve nor react with the explosive. The milling shall be accomplished using stainless steel balls or flint pebbles. Milling shall be continued until at least 98% of the sample passes through the 325 mesh

sieve. Only that portion passing the 325 mesh sieve shall be used for the test. The explosive shall be dried to constant weight at 55°C before being loaded in accordance with paragraph 5.5.2.

5.5.2 Loading Procedure. Bridge 40 plug assemblies (BUWEPS Drawing 457454) with a 2-mil-diameter tungsten wire flush with the plug surface (Fig. 3-9). Firmly attach the spacer (BUWEPS Drawing 652246) to the bridged plug assembly. Twenty bridged plug subassemblies each shall be loaded with the dry explosive prepared as in paragraph 5.5.1 by pressing the explosive flush ± 0.010 inch with the spacer at pressures of 4,000 and 20,000 psi respectively.

5.5.3 Firing Procedure. Each loaded unit shall be tested with an ohmmeter prior to firing to determine that the tungsten bridge wire is intact. The test unit shall then be placed explosive side down on an aluminum witness plate (Fig. 3-10) and fired in a safety chamber. Firing voltage shall be supplied by a fully charged 12 volt lead-acid automotive storage battery of at least 45 ampere hours capacity. The battery shall be connected to the test unit by a plunger type mercury relay (Macke electrical devices or equivalent) through appropriate wiring and safety interlocks. The total circuit resistance including the relay, wiring, and interlocks, but not the battery or test unit, shall not exceed 0.4 ohm. Testing shall continue until all 40 samples (only 20 samples are necessary for extrudable non-curing explosives) are tested, unless an individual test sample does not meet the requirement of paragraph 5.5.4.

5.5.4 Qualification Criterion. The candidate explosive shall be reported to have passed the hot wire ignition test and to be acceptable as a booster explosive as defined in paragraph 3.2.1 if none of the 40 samples show any evidence of reaction in the form of visible, audible, or measurable external change to the test explosive, the test unit, or the witness plate. The tungsten wire shall, however, have been burned out as determined by an ohmmeter test.

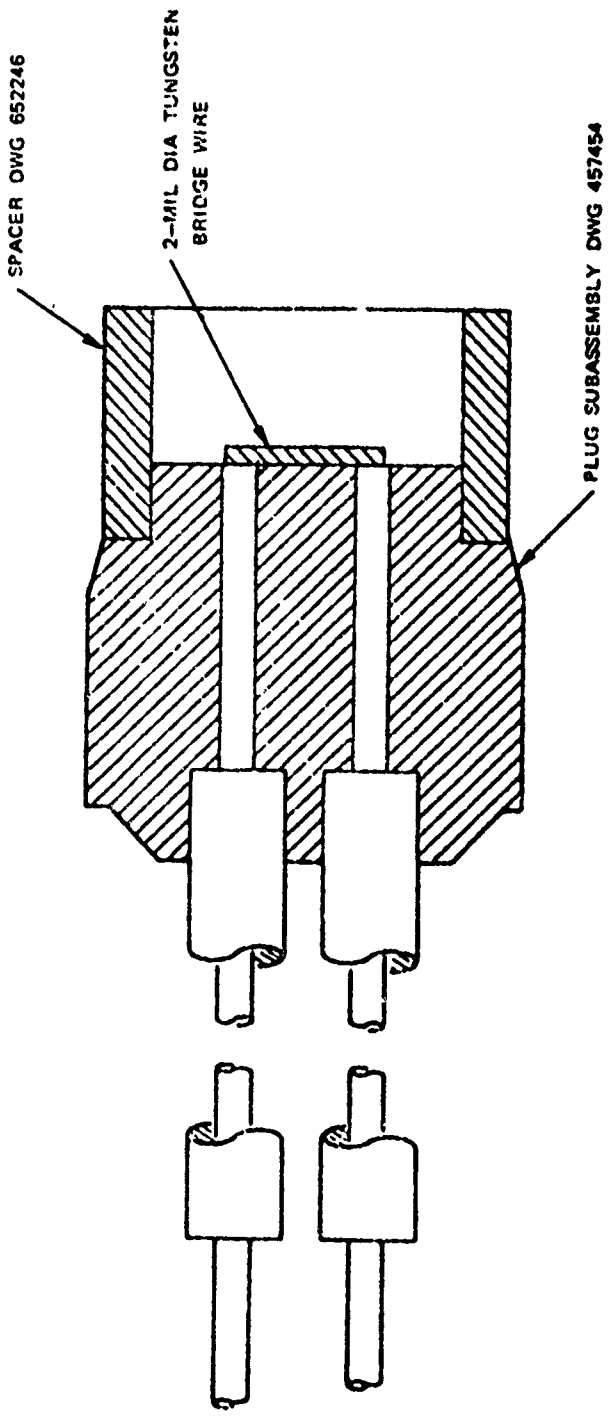


FIG. 3-5. Hot Wire Ignition Arrangement.

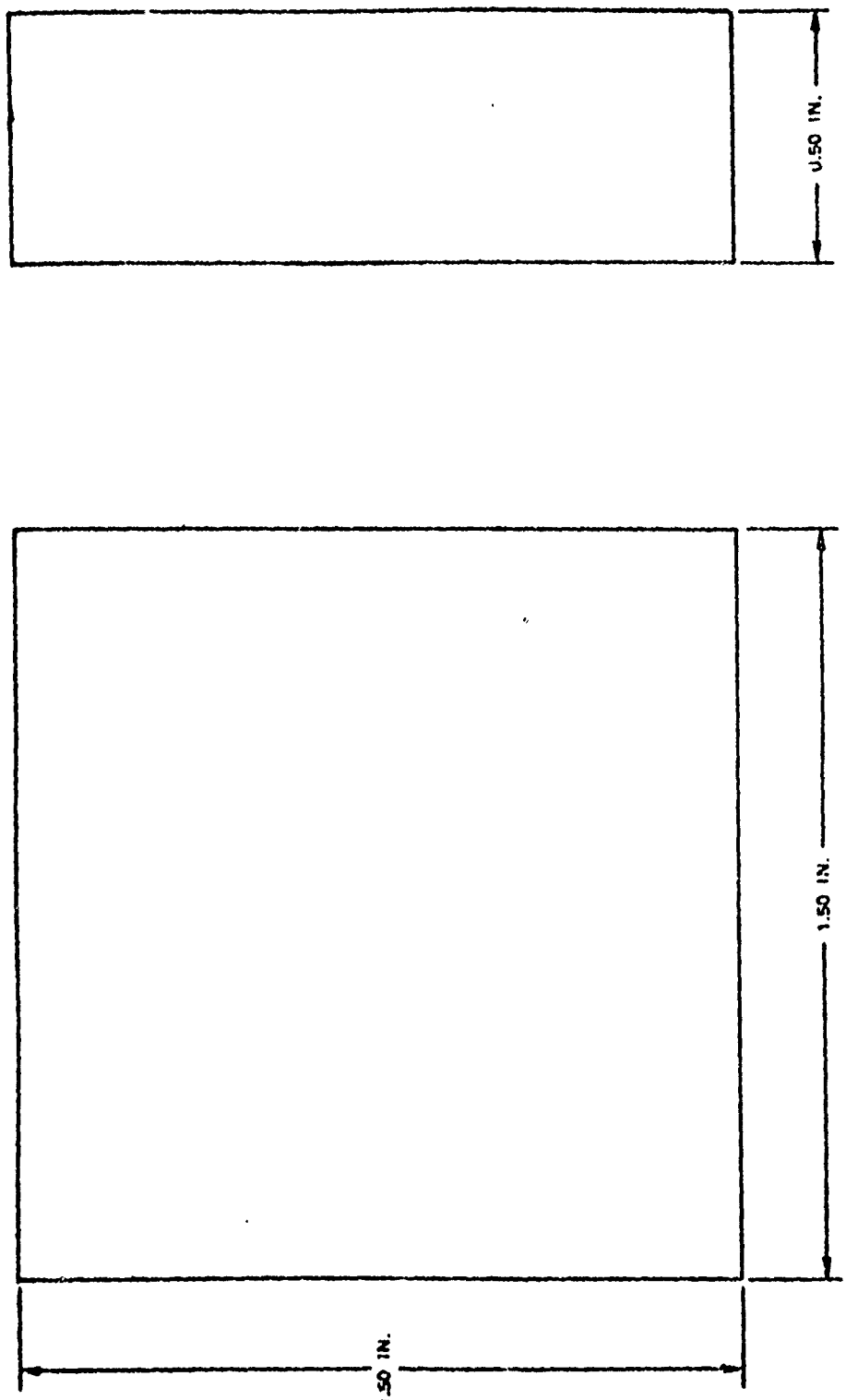


FIG. 3-10. Aluminum Dent Block.

5.6 Thermal Detonability (Bon-Fire) Test.

5.6.1 Test Arrangement. Each trial shall be arranged as shown in Fig. 3-11.

5.6.2 Specimens.

5.6.2.1 Specimen Preparation (Granular Explosives). The small column of explosive shall be pressed directly into the hole provided at 10,000 pounds per square inch. The length of the loaded increment shall not exceed its diameter. The large diameter components of the specimen may be either a pellet 0.930 $^{+0.000}_{-0.005}$ inch in diameter by 1.000 $^{+0.000}_{-0.010}$ inch long pressed at 10,000 pounds per square inch or it may be pressed directly into a 1 inch length of steel tubing 15/16 inches in diameter by 24 gauge wall.

5.6.2.2 Specimen Preparation (Cast, Molded, and Extruded Explosives). Specimens of cast, molded, or extruded explosives shall be prepared in accordance with paragraph 4.4.2. (Extrudable non-curing materials may be extruded directly into the hole.) The specimens shall be of dimensions indicated in Fig. 3-11.

5.6.3 Test Procedure. Each trial shall be arranged as shown in Fig. 3-11 in a bombproof shelter or firing chamber adequate for protection against the effects of detonation of a charge of the size shown. After personnel have retreated to a protected position, or the firing chamber has been closed, the thermite mixture shall be ignited. Personnel shall not approach the charge nor shall the firing chamber (if used) be opened until 1 hour after the ignition of the thermite.

5.6.4 Qualification Criterion. The candidate explosive shall be reported to have passed the thermal detonability test and to be acceptable as a booster explosive as defined in paragraph 3.2.1 if there are no explosions in 20 of only 20 trials.

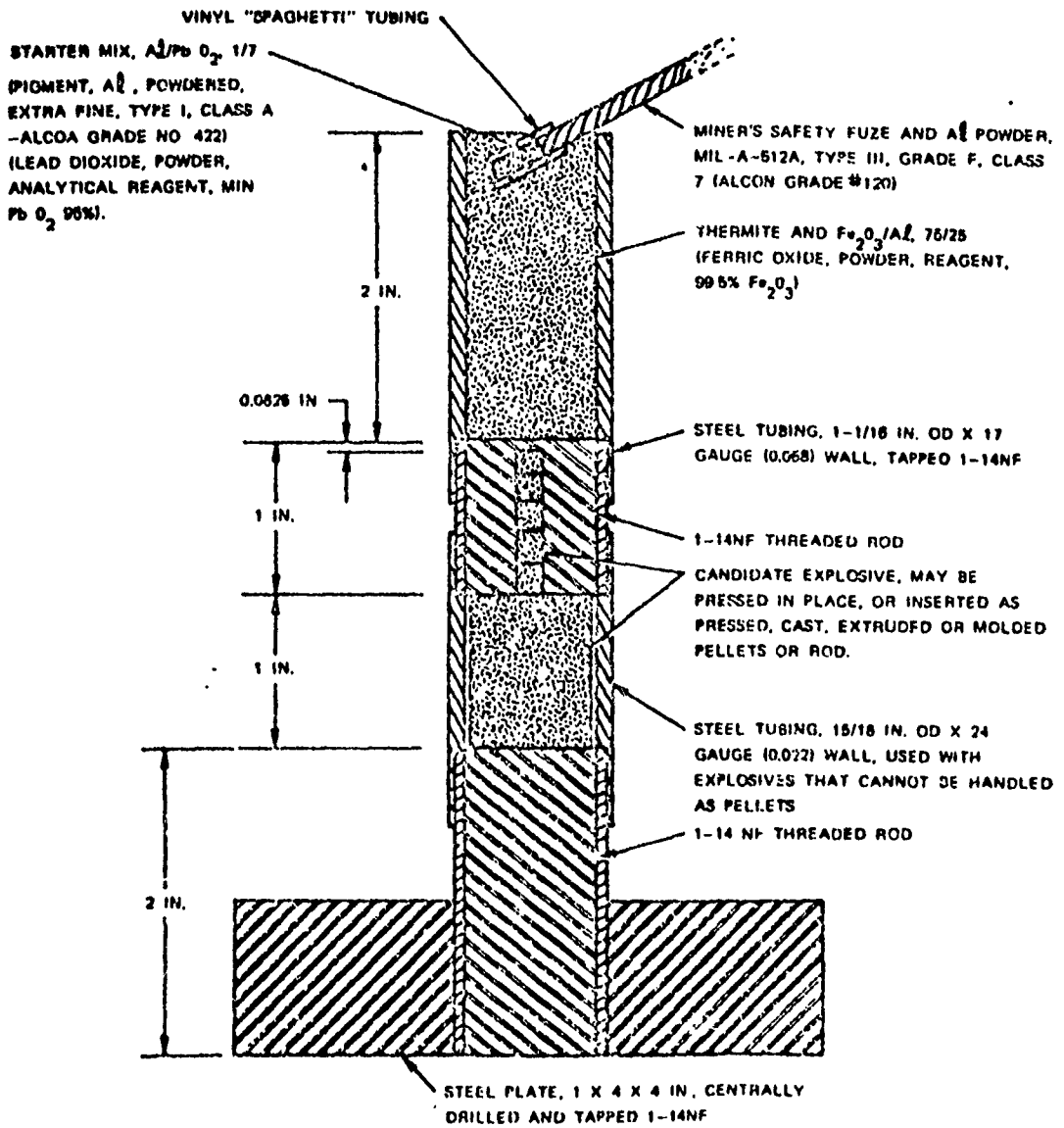


FIG. 3-11. Bon-Fire Test Arrangement.

5.6.5 Criterion for Explosion. For the purpose of this document, any reaction which causes detectable damage to the witness plate shall be considered an explosion.

5.7 Electrostatic Sensitivity Test.

A representative sample of the proposed new booster explosive shall be subjected to the electrostatic sensitivity test described in the following paragraphs using apparatus in accordance with drawings and specifications listed in PL/DL 618104.

5.7.1 Experimental Procedure and Conditions. Electrostatic sensitivity tests for this requirement shall be performed using apparatus in accordance with the drawings and specifications listed in PL/DL 618104 and the following experimental conditions.

5.7.1.1 Electrode Adjustment. Before starting a test or when the upper (needle) electrode is replaced in accordance with paragraph 5.7.3.2, it is necessary to readjust the electrode spacing. This is accomplished by bringing the electrodes in contact, adjusting the dial indicator so that the pointer is at zero and then turning the adjusting screw to move the electrodes 0.050 inch apart as indicated by the dial indicator (one revolution) (Fig. 3-12).

5.7.1.2 Voltage Adjustment. Before starting a test, the outout of the high voltage power supply shall be adjusted to 10,000 ± 100 volts. This can be checked by pressing the charge switch button and reading the electrostatic voltmeter. (See Fig. 3-13.) After releasing the charge switch button, advance the grounding bar to contact the upper electrode.

5.7.1.3 Specimen Preparation. A specimen is prepared for each trial by inserting approximately 20 milligrams (enough to cover the bottom but not to fill the charge cavity more than about one-third full) of the explosive in the charge cavity (the hole in the washer) of a lower electrode assembly. For cast, molded, and cured extruded explosive it will be necessary to pulverize the cured or formed samples in a ball mill as described in paragraph 5.5.1. Since some explosives are subject to segregation with respect to particle size or components of mixtures,

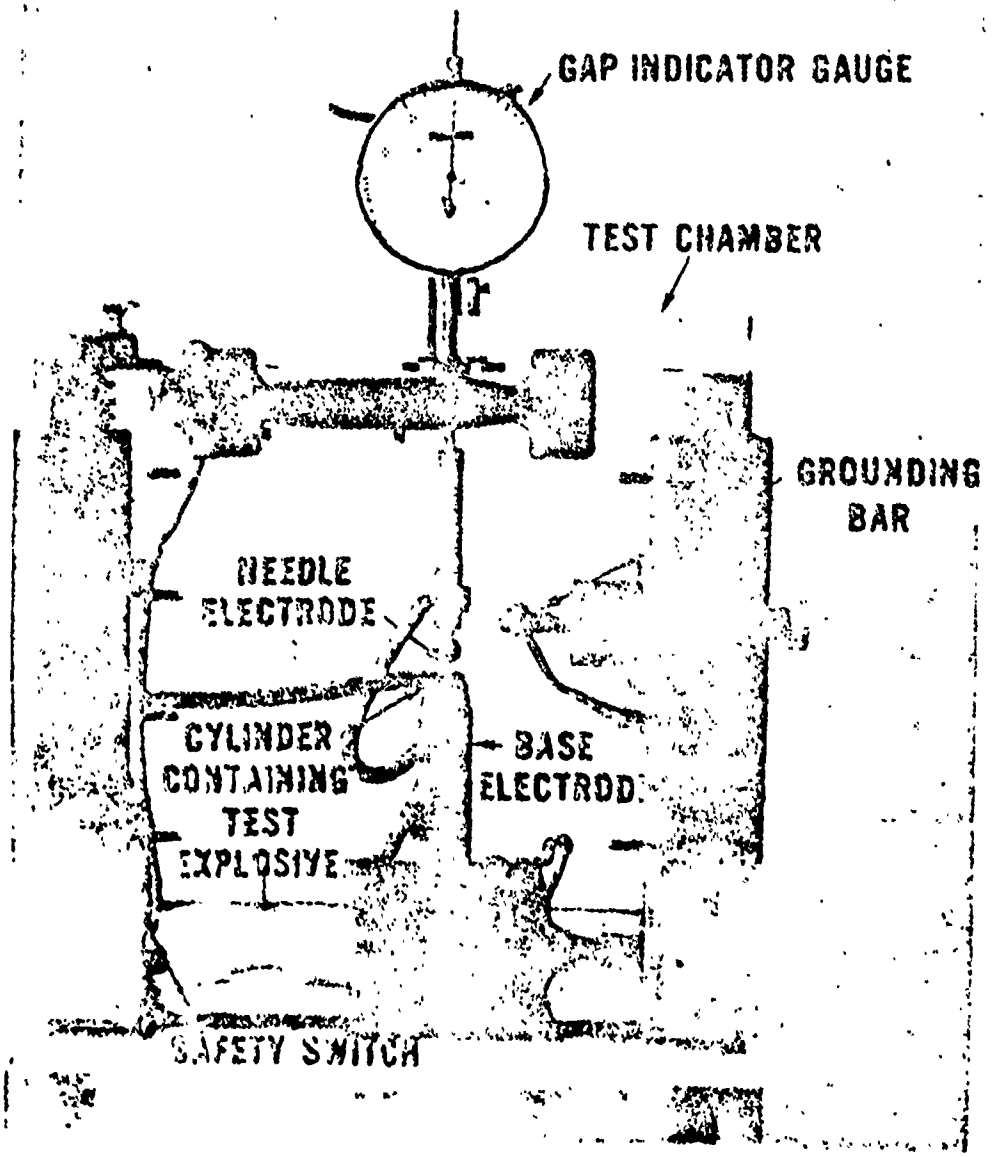


FIG. 3-12. Explosive Test Chamber.

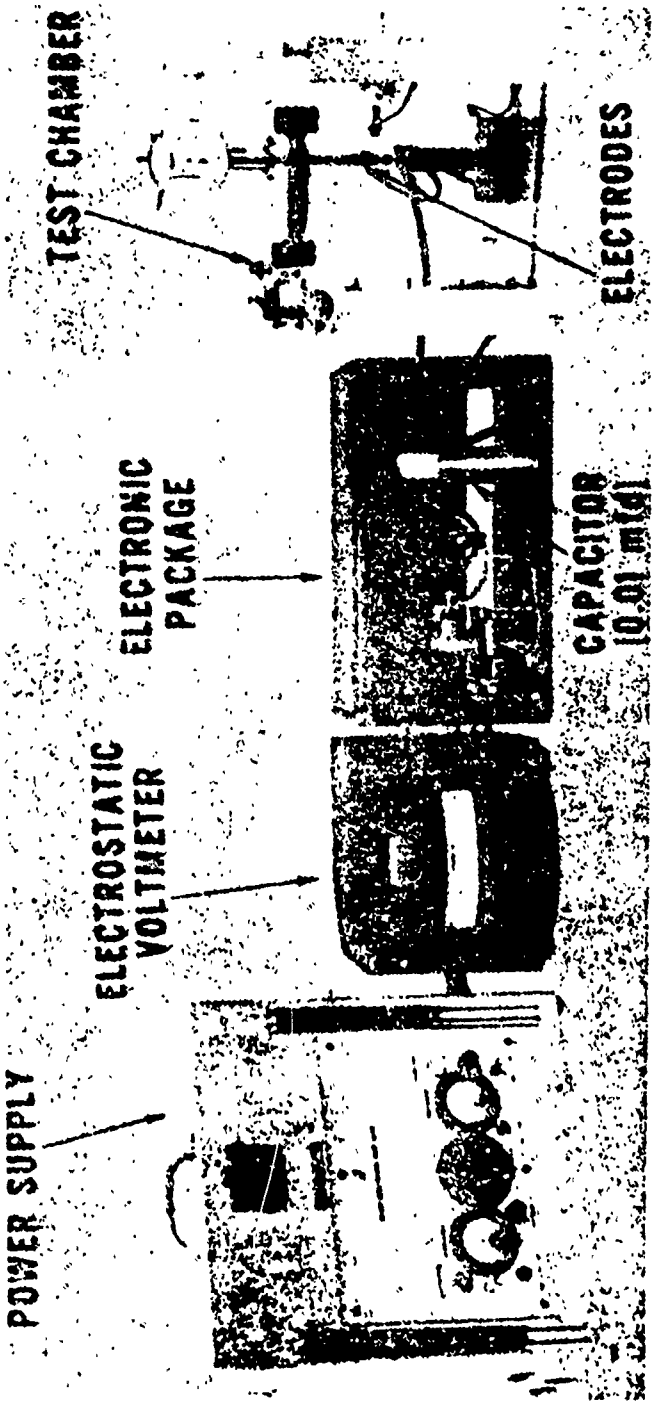


FIG. 3-13. Fixed Gap Electrostatic Discharge Apparatus--Model #2.

care should be exercised to insure that, in the course of a test, the material actually used constitutes a representative sample, with respect to both particle size distribution and composition. Since segregation is possible in use as well as in testing, it is not necessary that each specimen have the exact composition and particle size distribution of the sample.

5.7.1.4 Procedure for Each Trial (Granular, Cast, Molded, and Curing Extrudable). The procedure for each trial shall be as follows.

5.7.1.4.1 Move shorting bar into contact with upper electrode assembly to discharge any residual charge on the capacitor. Raise upper electrode by means of the dial indicator lifting lever. Do not put hands into test chamber before shorting upper electrode assembly. Insert lower electrode assembly containing explosive specimen prepared according to paragraph 5.7.1.3. Close door. Lower upper electrode to position (limited by adjusting screw as adjusted per paragraph 5.7.1.1) 0.050 inch above the lower electrode. Retract shorting bar to its limiting position.

5.7.1.5 Procedure for Each Trail (Non-Curing Extrudable). Prepare specimen per paragraph 5.7.1.3 by extruding the explosive directly into the hole in the lower electrode. The explosive charge should not fill the cavity to more than 1/3 full. Move shorting bar into contact with the upper electrode assembly and raise the upper electrode by means of the dial indicator lifting lever. Do not put hands into test chamber before shorting the upper electrode assembly. Insert the lower electrode assembly containing the explosive specimen and close the door. Lower the upper electrode to the position limited by the adjusting screw previously adjusted per paragraph 5.7.1.1. Retract the shorting bar to its limiting position. Press the charge switch until the capacitor is charged to 10,000 ± 100 volts as indicated by the electrostatic voltmeter. Release the charge switch and note whether or not there is a spark and drop in voltage as indicated by the voltmeter. If a discharge does occur proceed with the testing making sure that discharge occurs on each trial.

If a discharge does not occur in any trial, readjust the upper electrode per paragraph 5.7.1.1 lowering the upper electrode in 0.005 inch steps until the test can be completed by running 20 consecutive trials with a discharge occurring in every trial. To pass the test, the requisite number of trials must be made for the final electrode gap setting ignoring failures to fire in all previous trials even though a spark may have occurred.

5.7.2 Qualification Criterion. A candidate explosive shall be reported to have passed the electrostatic sensitivity test and to be acceptable as a booster explosive as defined in paragraph 3.2.1 if there are no reactions in the 20 consecutive trials.

5.7.2.1 Evidence of Reaction. An audible report which can be distinguished from the noise of the spark, and/or visible smoke or flame shall be considered evidence of reaction.

5.7.3 Other Requirements. The test shall not be considered valid nor the results reported unless the following conditions have been met.

5.7.3.1 Relative Humidity. The relative humidity shall not exceed 40% as measured by a wet-and-dry bulb thermometer, or instrument of similar reliability. Note - very low humidity increases the hazard of accidental initiation by discharge of body or stray static charges.

5.7.3.2 Electrode Replacement. The upper (needle) electrode shall be replaced after it has been used in 10 trials, after any trial in which there is evidence of reaction, when a test of a new explosive sample is started, or at any time that the operator observes any change in its condition (whichever of these circumstances occurs first).

5.7.3.3 Periodic Apparatus Check. The apparatus shall be checked at least every 10 working days by subjecting a sample of lead azide (per MIL-L-3055) to the static sensitivity test. Data obtained subsequent to a check test shall not be officially reported or used in the qualification of any candidate booster explosive until another apparatus check test has been performed. The procedure and conditions shall be as

outlined above except that the voltage shall be 5,000 ± 50 volts. The check test shall consist of 10 trials. The apparatus shall be considered to be performing satisfactorily if all 10 specimens explode, as evidenced by a loud report. If each trial does not result in an explosion, evidenced by a loud report, a detailed examination of the apparatus shall be made to determine the cause of the failure to initiate lead azide, and all data which have been obtained since the last satisfactory check test discarded.

5.8 Friction Sensitivity Test.

A representative sample of the proposed booster explosive shall be subjected to the friction sensitivity test as described in the following paragraphs.

5.8.1 Experimental Conditions and Procedures. Each trial shall be performed using the arrangement as shown in Fig. 3-14 through 3-18 and the following experimental conditions.

5.8.1.1 Specimen Preparation (Cast, Molded, and Extruded Explosives). The method of preparation of test samples shall depend upon the properties of the explosive and the intended procedure to be used in fabrication for use as a booster explosive. Pellets of the test explosive shall be fabricated to the configuration as shown in Fig. 3-16 in accordance with paragraph 4.4.3.

5.8.1.2 Specimen Preparation (Granular Explosives). Four tenths of a gram of the test explosive shall be pressed into the specimen holder at 20,000 psi (a dead load of 2,200 pounds) to the configuration shown in Fig. 3-14. Note - since some explosives are subject to segregation with respect to particle size or components of mixtures, care should be exercised to insure that, in the course of a test, the material actually used constitutes a representative sample, with respect to both particle size distribution and composition.

5.8.1.3 Abrasive Strip Preparation. The abrasive strip shall consist of spring steel strip 0.015 inch thick by 2.000 inches wide by 18.0 inches long, hardened and tempered to a hardness of Rockwell C48/51 (Rockwell

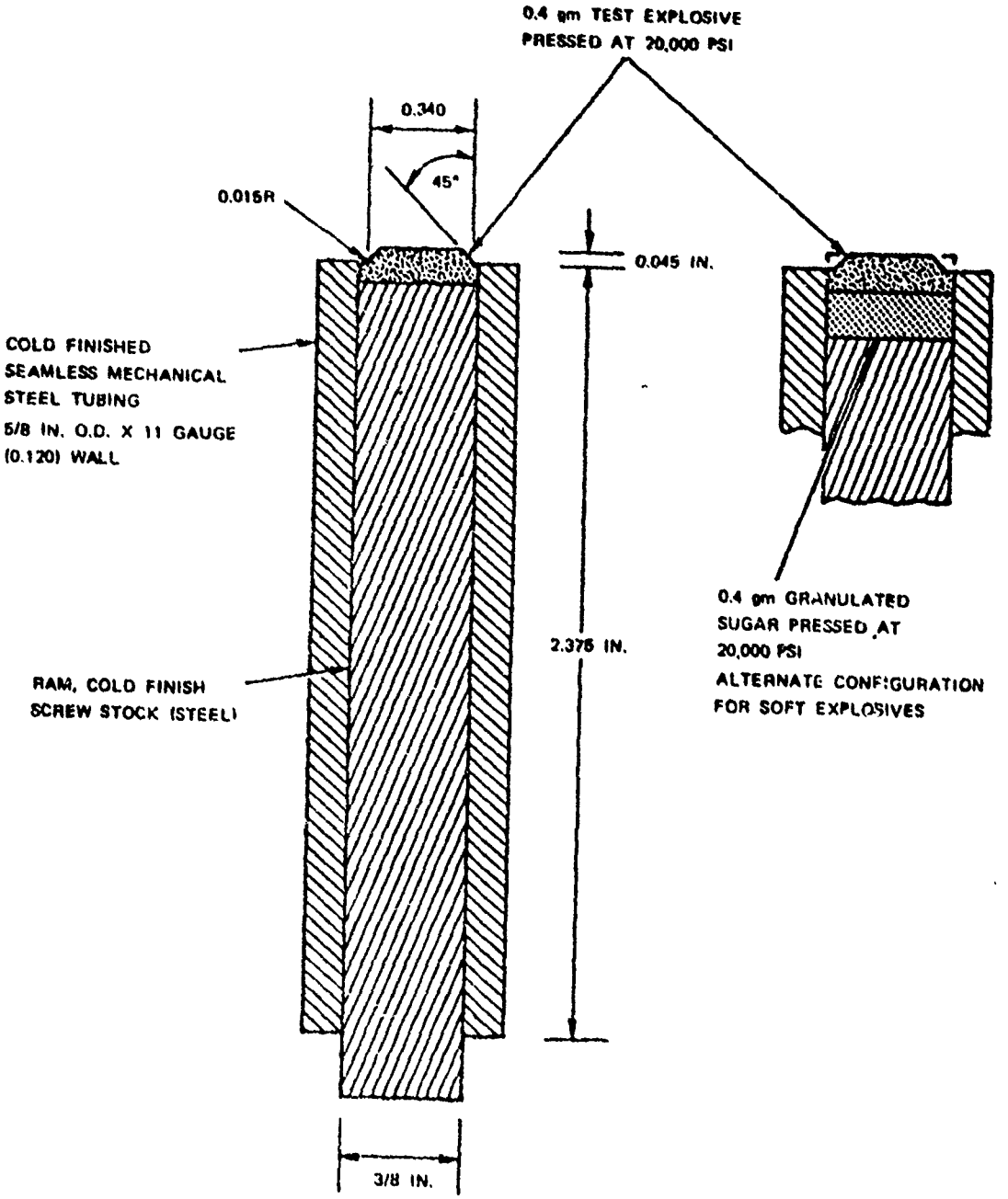


FIG. 3-14. Friction Sensitivity Test Specimens in Holder.

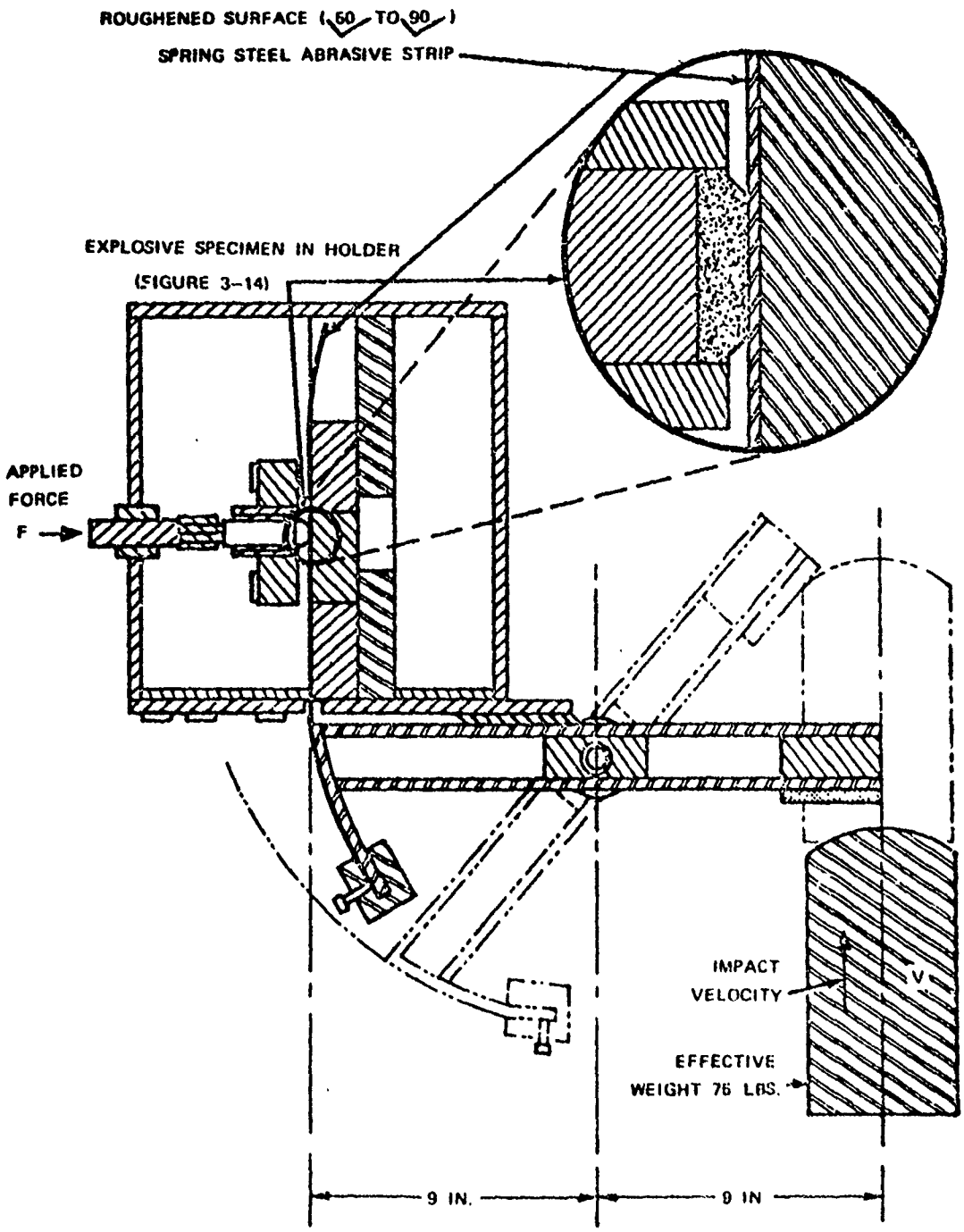
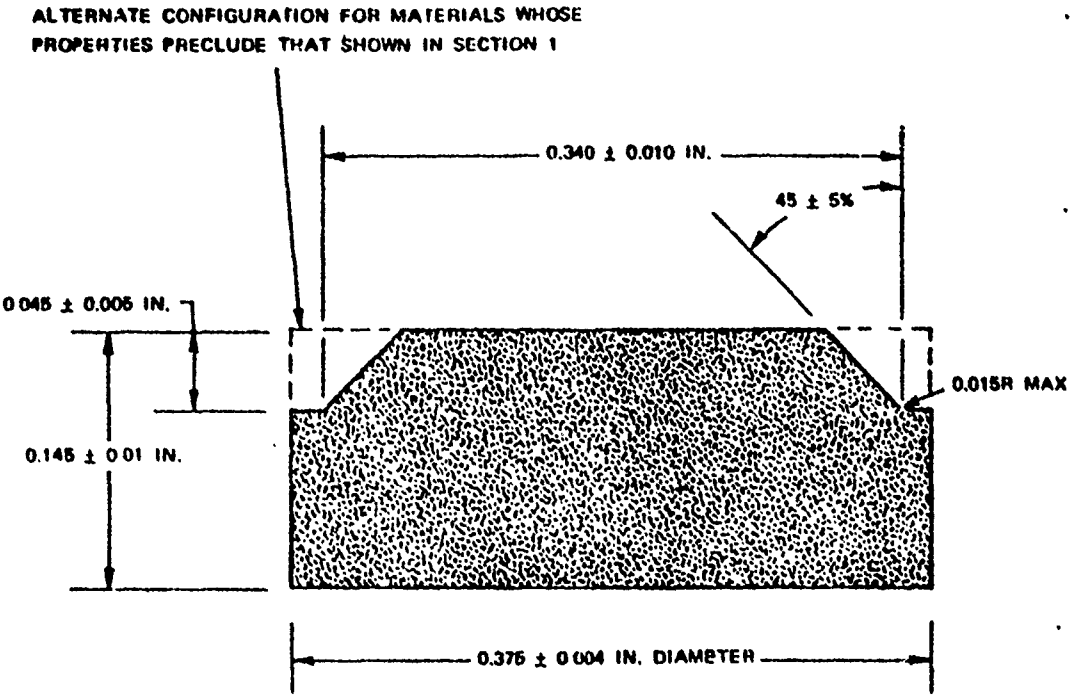


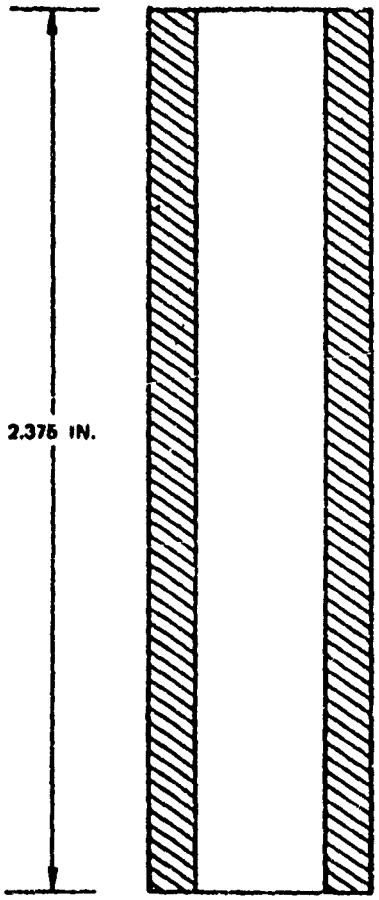
FIG. 3-15. Friction Sensitivity Apparatus.



PELLETS OF TEST EXPLOSIVES MAY BE FORMED BY PRESSING, CASTING, MOLDING, MACHINING ISOSTATIC PRESSING, EXTRUSION OR BY OTHER MEANS OR BY A COMBINATION OF THE ABOVE MENTIONED FABRICATION METHODS.

NOTE. FOR MOST OF THE MORE COMMON BOOSTER EXPLOSIVES, APPROXIMATELY 0.4 GRAM OF EXPLOSIVE WILL BE SUFFICIENT. PRESSED GRANULAR EXPLOSIVES SHALL BE PRESSED AT 20,000 PSI

FIG. 3-16. Test Specimen Configuration.



COLD FINISHED SEAMLESS
MECHANICAL STEEL TUBING
5/8 IN. O.D. X 11 GAUGE
(0.120) WALL
O.D. 0.625 ± 0.005 IN.
I.D. 0.385 ± 0.005 IN.

NOTE: THESE TOLERANCES ARE SMALLER THAN STANDARD COMMERCIAL TOLERANCES; HOWEVER, DUE TO IMPROVEMENTS IN MILL EQUIPMENT AND PRACTICES, MOST RECENTLY PRODUCED TUBING WILL FALL WITHIN THESE TOLERANCES

FIG. 3-17. Specimen Holder Tube.

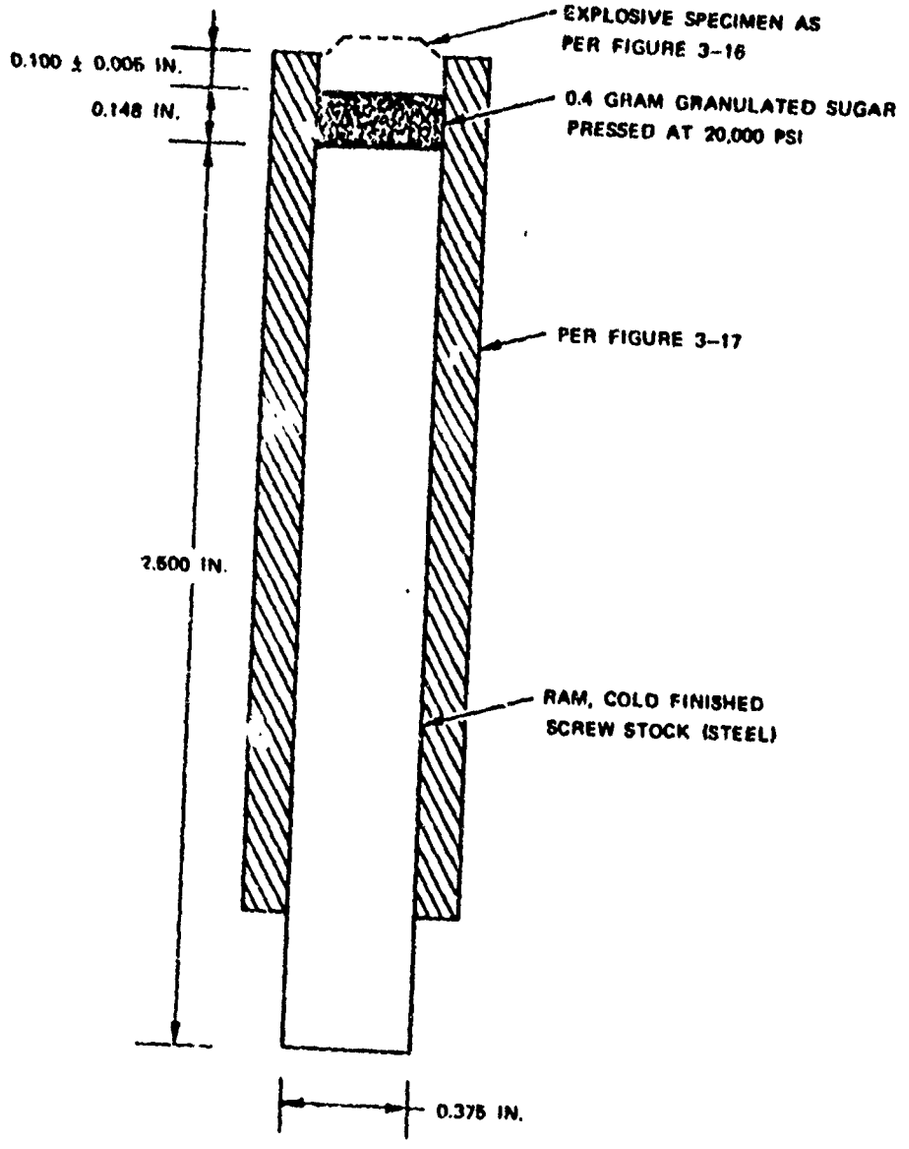


FIG. 3-18. Specimen Holder Assembly.

30 N 66.5/69.5) and roughened as follows: On one side, over an area including the entire width and from one end to a point not less than 6.5 inches from the end. The roughening is accomplished by means of a belt sander using a cloth belt with resin bonded, 60 grit silicon carbide abrasive (Carborundum, Locking, Type 865F, or equivalent). While sanding, the long axis of the stainless steel strip shall be perpendicular to the motion of the sanding belt. The sanding shall continue until all temper color has been removed from the area defined above and the apparent texture of this area is uniform. Fresh sanding belts, which have not been used for other operations, shall be used and not more than five spring steel straps shall be roughened with the same belt. The roughness shall be such as to have an average deviation of not less than 50 nor more than 90 microinches, as measured by means of a profilometer, from the mean surface.

5.8.1.4 Procedure for Each Trial. The procedure for each trial shall be as follows (see Fig. 3-15).

5.8.1.4.1 Locate witness block with the help of spacer block, as shown in Fig. 3-15, so that witness block is approximately centered with center line of specimen support bushing.

5.8.1.4.2 Coat back (opposite side to that roughened) of spring steel abrasive strip with a two to one mixture of S.A.E. 30W engine oil and flake graphite (Dixon Crucible Co. No. 635 or equivalent). Roughened surface shall be kept clean.

5.8.1.4.3 Install spring steel abrasive strip as shown in Fig. 3-15, with roughened surface facing specimen support bushing, and bend end of spring steel strip (opposite end to that roughened) around heel of jerk lever. Clamp as shown in Fig. 3-15.

5.8.1.4.4 Insert specimen in specimen holder assembly. (See Fig. 3-14 and 3-15.) Insert specimen holder assembly with specimen in place in support bushing and apply normal force of 1,675 ± 25 pounds to ram of specimen holder. (Either hydraulic pressure or dead weight may be used

to apply and maintain the normal force. It may be advantageous, particularly with dead weights, to use a lever system or other force multiplying mechanism.)

5.8.1.4.5 The "boom box" shall be closed, the safety bar (which restrains the pendulum) removed, the handle of the pendulum adjusted so that its center of gravity is 18 ± 0.5 inches above its low equilibrium point (at which it strikes the jerk lever), and the pendulum released. If the apparatus is performing normally, the spring steel abrasive strip will be jerked entirely free from the boom box (except for pieces which may be broken or torn from the strip as the result of an explosion).

5.8.1.4.6 The pendulum shall be returned to its top position, the safety bar replaced, the boom box opened, the normal force removed, and the specimen holder removed from the support busing. (When an explosion has expanded the specimen holder, it is usually necessary to remove the witness block and remove the specimen holder through the hole in the witness block support.)

5.8.2 Qualification Criterion. The candidate explosive shall be reported to have passed the friction sensitivity test and to be acceptable as a booster explosive as defined in paragraph 3.2.1 if there are no explosions in 20 of only 20 trials.

5.8.2.1 Criterion of Explosion. For purposes of qualification, any reaction which results in an expansion of 0.005 inch or more of the specimen holder or produces a dent more than 0.002 inch deep in the witness block, or both, shall be considered an explosion.

5.8.3 Other Requirements. The test shall not be considered to be valid nor shall the results be reported as part of the qualification data for the explosive under test unless the following conditions have been met.

5.8.3.1 Relative Humidity. The relative humidity shall not exceed 80% as measured by a wet and dry bulb thermometer or instrument of similar reliability.

5.8.3.2 Periodic Apparatus Check. The apparatus shall be checked subsequent to or concurrent with each series of qualifying tests, by subjecting a sample of tetryl (MIL-T-00339A) and a sample of PETN, (Pentaerythritol tetranitrate) (per MIL-P-387A) to the friction sensitivity test. Data obtained subsequent to a check test shall not be officially reported or used in the qualification of any candidate booster explosive until another apparatus check test has been performed. (Check test trials may be interspersed among qualification test trials in a random or systematic order so that data can be developed concurrently.) The procedure and conditions shall be as outlined above. The apparatus shall be considered to be performing satisfactorily if the PETN fails and the tetryl passes in accordance with the criterion outlined in paragraphs 5.8.2 and 5.8.3. If either the PETN passes or the tetryl fails, a detailed examination and calibration of the apparatus shall be made to detect any change in test conditions, and all data obtained since the last satisfactory check test discarded.

5.9 Detonation Velocity Test.

Detonation Velocity Tests will be conducted in accordance with Ref. 1 and 2.

REFERENCES FOR CHAPTER III

1. Campbell, A. W., M. E. Malin, T. J. Boyd, Jr., and J. A. Hull. Rev. Sci. Instru. 27 (8), 567 (1956).

2. Amester, A. B., P. A. Kendall, L. V. Veillette, and B. Harrell. Rev. Sci. Instru. 31, 188 (1960).

CONTENTS

1. SCOPE

1.1 Scope. This chapter establishes environmental and performance tests which are required for final qualification of a booster explosive to be used in naval weapons. The tests set forth herein represent the minimum amount of data required on an explosive to be used in a proposed service item before approval can be given for service use of that explosive in that item. This does not supersede the requirements of MIL-STD 331 for the fuze itself. If the fuze is subjected to the requirements of MIL-STD 331 the following are sections applicable to the explosive.

1.2 Application. This chapter applies to any explosive which is loaded into a component whose detonation would be communicated to the main charge of a weapon when that weapon's fuze is in either safe or arm condition.

1.3 Sample Size. The sample sizes specified in each test are only the minimum necessary to perform the test. The sizes are not considered sufficient to provide the basis for a statistical evaluation relative to quality or reliability of the test item. Additional tests may be required for certain systems.

1.4 Definitions.

1.4.1 Safe. For the purpose of this chapter, safe is defined to be the condition of the item for which no undue hazard would exist to personnel or equipment engaged in handling, shipping, or disposing of the unit.

1.5 Applicable Documents.

MIL-STD 331	Environmental and Performance Tests for Fuzes and Fuze Components.
MIL-STD 210A	Climatic Extremes for Military Equipment.

2. GENERAL REQUIREMENTS

2.1 Test Conformance. Each individual test shall be performed in the manner and sequence specified herein. Any deviation or modification essentially defeats the standardization which is an objective of this

document. Therefore, when a test is not performed as specified, the test report shall so indicate, documenting the difference(s), and in general, shall not be reported as performance under this document.

2.2 Test Equipment.

2.2.1 Capability. All equipment required for the tests must be capable of providing or meeting the conditions required.

2.2.2 Accuracy of Test Equipment. The accuracy of instruments and test equipment used to control or monitor the test parameters shall be verified periodically (at least every 12 months, and preferably once every 6 months). All instruments and test equipment used in conducting the tests specified herein shall:

a. Conform to laboratory standards whose calibration is traceable to the U. S. Bureau of Standards.

b. Have an accuracy of at least one-fourth the tolerance for the variable to be measured. In the event of conflict between this requirement and any accuracy requirement in any one of the tests of this document, the accuracy requirement of the test being used shall govern.

c. Be appropriate for measuring the conditions concerned.

2.3 Test Conditions. Unless otherwise specified herein, all measurements and tests shall be performed at ambient temperature, pressure, and relative humidity. Whenever these conditions must be controlled in order to obtain reproducible results, a reference temperature of 23°C (73°F), an atmospheric pressure of 30 inches of mercury, and a relative humidity of 50 percent shall be used together with whatever tolerances are required to obtain the desired precision of measurement. Actual test conditions shall be recorded during the test period whether controlled or not.

2.3.1 Installation of Test Item. Unless otherwise specified the test item shall be installed, mounted, attached to or placed in the test equipment in a manner that will simulate service usage. If fixtures or adaptors are required they shall be designed to provide the same simulation. Plugs, covers, plates, cables, and accessory items used in service shall remain

in place. When mechanical or electrical connections on the test item are not used, the connections shall be provided the same amount of protection which is provided during service use.

2.3.2 Tolerance of Test Conditions. The maximum allowable tolerances of test conditions (exclusive of accuracy of instruments), unless otherwise specified in any of the tests of this document shall be as follows:

a. Temperature: ±2°C (3.6°F).

b. Pressure: When measured by devices such as manometers ±5 percent or 0.05 inches of mercury, whichever provides the greater accuracy. When measured by devices such as ion gauges, ±10 percent to 1×10^{-5} torr.

c. Relative Humidity: +5 percent, -0 percent.

d. Vibration Amplitude: Sinusoidal, ±10 percent; random, ±30 percent.

2.3.3 Preconditioning and Stabilization. Unless specified no preconditioning or stabilization will be required. When preconditioning is required the conditions shall be instituted and brought to the level for the time specified, at which point the test shall begin. When stabilization is required the conditions shall be held at the level for the time specified. Checking operation of or adjusting test equipment with the test item installed or exposed, at any time (pre-test, during test, post-test), shall be kept at a minimum. Such time shall be considered a part of the test time, if time is a factor of test item performance or life.

2.4 Examination and Test Criteria.

2.4.1 Visual Examination. At the beginning or completion of any test required herein or when test exposure is considered to have affected the test item, a visual examination shall be made of the item and any damage observed shall be recorded in the test record. The extent of the visual examination shall be governed by the nature of the test item and the damage suspected or incurred. The examination shall not be performed in a manner which interferes with any subsequent performance or operational test which is necessary to determine conformance to the criteria for passing the test.

3. MANDATORY REQUIREMENTS

3.1 Sequence. The tests shall be conducted in the sequence and with no less than the number of units shown in Fig. 4-1.

3.2 Transportation Vibration.

3.2.1 Description of Test. The test consists of vibrating explosive components according to a specified schedule of frequencies, amplitudes and durations while being maintained at prescribed temperature conditions.

3.2.2 Criteria for Passing Test. The units must be safe to handle and dispose of following this test as determined by inspection.

3.2.3 Test Equipment.

3.2.3.1 The vibration equipment required to conduct this test may be any remotely controlled vibration machine, such as mechanical (direct-drive), mechanical reaction or electrodynamic type, producing essentially rectilinear simple harmonic motion and having the necessary capacity for force output, weight of load, and frequency range. Vibration machines which produce complex motion in a combination of circular or rocking modes may be used. However, the amplification conditions which occur with this type of equipment, due to variations of load sizes and shapes, should be determined and the maximum acceleration point established for use in monitoring. Frequency control may be continuous or by discrete steps, using logarithmic distribution. The vibration equipment must be capable of covering the frequency range of 10 to 500 cycles per second (cps) ±3 percent. Amplitude capabilities required for the 10 to 60 cps range shall be 0.10 ± 0.01 inch double amplitude or 2 ± 0.2 g peak, whichever is lesser, and for the 60 to 500 cps range 5 ± 0.2 g peak.

3.2.3.2 Rigid mounting fixtures which simulate the service assembly of the units must be provided. In designing test fixtures, or in devising any method of securing test samples to the vibration table, it is desirable that any component or combination of components employed in the mounting system have a natural frequency at least three times the maximum frequency to be encountered in the test schedule.

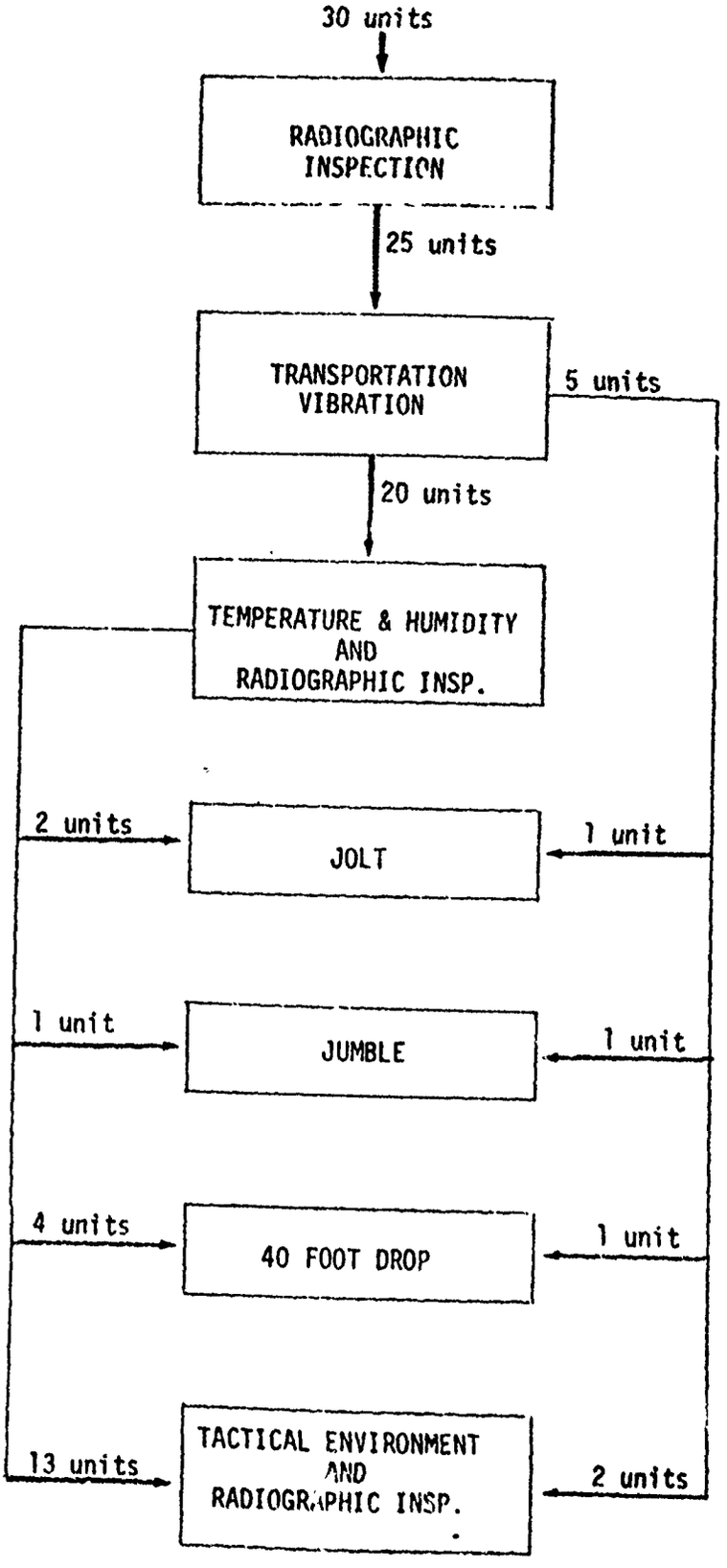


FIG. 4-1. Sequence of MIL-STD 331 Tests.

3.2.3.3 The instrumentation required shall be capable of measuring, within the prescribed limits, the frequency and amplitude of the applied vibration and the conditions of temperature specified.

3.2.3.4 Temperature conditioning equipment shall be required to establish and maintain the fuze at the specified temperature levels during test.

3.2.4 Test Procedure.

3.2.4.1 Temperature Conditions. Three conditions are required for the complete test: (1) -65 ± 4°F, (2) +86 ± 18°F, and (3) +160 ± 4°F. Each unit shall be subject to only one temperature. The units shall be divided among the three temperatures as equally as possible. They shall be temperature conditioned prior to the test at the value chosen and maintained at that temperature level for the duration of the test.

3.2.4.2 Vibration Conditions. The units shall be mounted in the test fixture and securely fastened to the vibration table. Vibratory excitation shall be applied parallel to each of three major axes in turn: (1) the longitudinal axis (line of flight), (2) a first transverse orthogonal axis, and (3) a second transverse orthogonal axis. The two transverse axes and the sense of the vibration (nose up or nose down) along the longitudinal axis shall be chosen to expose the most critical or vulnerable positions of the unit to the vibration. The vibration schedule used shall be one of the following specified, dependent upon the method of frequency control of the vibration equipment.

3.2.4.2.1 Cycling Method. The vibration schedule of Table 4-1 shall be used. Frequency shall be controlled by logarithmic sweep. Total test duration shall be 24 hours plus the time spent at resonant frequencies. The resonant frequencies should be determined during the first cycling period for each axis position. When resonant conditions are not observed within the specified vibration schedule the resonance vibration shall consist of performing four additional sweeps, two over the 10-60-10 cps range and two over the 60-500-60 cps range, 15 minutes each, totaling 60 minutes.

TABLE 4-1. Vibration Schedule (Cycling Method).

Type	Frequency, cps	Input amplitude	Cycles[a]
Cycling	10-60-10	0.10 ± 0.01 inch double amplitude or 2 ± 0.2 g peak, whichever is lesser	10
Cycling	60-500-60	5 ± 0.2 g peak	14
Resonance	As determined (would be single frequency points)	As indicated above in the specific frequency range	Dependent upon the number of resonant points

[a]Duration at each cycle and at the resonant frequency shall be 20 minutes. The total cycling test time in each axis shall be 4 hours and the test time at resonant points shall be 20 minutes times the number of resonant frequencies (i.e., 20 minutes at each resonant point).

3.2.4.2.2 Discrete Step Method. The vibration schedule of Table 4-2 shall be used. Total test duration shall be 24 hours plus the time spent at resonant frequencies. The resonant frequencies may occur between the frequency steps and additional investigation will be necessary to determine whether resonant conditions exist. Intermediate frequency points may be studied to identify either resonant points or resonant bands. The item shall then be vibrated at each fixed point or within each resonant band for 15 minutes. When resonant conditions are not observed within the discrete frequency vibration schedule the resonant vibration shall consist of repeating vibration at four frequency steps, 10 cps, 46 cps, 152 cps, and 500 cps for 15 minutes at each frequency. Amplitudes of vibration shall be as specified in Table 4-2 for the stated frequency.

3.2.4.3 Upon completion of vibration, radiographic inspection is required. In general, the results of vibration tests are manifest in varying degrees of abrasion or loosening of components. Distinction between reasonable wear and borderline or serious damage, significant in terms of safety or operability, must be made on the basis of engineering judgment. Examine the item for conformance with paragraph 3.2.2.

TABLE 4-2. Vibration Schedule (Discrete Step Method).

A. Frequency, cps

Step	Axis		
	Longitudinal	Transverse 1	Transverse 2
1	10	12	14
2	17	20	24
3	28	33	38
4	46	54	65
5	76	91	107
6	128	152	178
7	212	250	297
8	350	417	500
9	Resonant frequency as determined	Resonant frequency as determined	Resonant frequency as determined

B. Vibration Amplitude

1. Input amplitude shall be 0.10 ± 0.01 inch double amplitude or 2 ± 0.2 g peak, whichever is lesser, for frequencies below 60 cps.

2. Input amplitude shall be 5 ± 0.2 g peak for frequencies above 60 cps.

C. Duration

1. Duration at steps 1-8 (fixed frequency) per axis shall be 60 minutes per step.

2. Duration at step 9 per axis shall be 15 minutes per resonant frequency.

3.2.5 Background Information. (Not a mandatory part of this test.)

3.2.5.1 Vibration Schedules. The schedules utilized in this test have been developed following extensive measurements of accelerations during transportation in a variety of vehicles. The test as described is consequently a simulation test, and the units must not be adversely affected by it.

3.2.5.2 Resonance Studies. The resonant frequency of the total weapon structure may not be the most damaging. Individual components of the structure will have their own natural frequency of resonance and may experience greater g-amplification and damage at their own resonance than at the mass resonance. Therefore, it is suggested that studies of the response of individual components be made to provide the proper information as to resonance effect.

3.2.5.3 Mechanical Vibration Effects. In general, the results of vibration tests are manifest in varying degrees of abrasion or loosening of components. Distinction between reasonable wear and borderline or serious damage, significant in terms of safety or operability, must be made on the basis of engineering judgment, including studies under dynamic operating conditions where practicable.

3.2.5.4 Temperature Conditions. Temperatures are combined with the vibration environment to simulate the service use conditions. Temperature conditions of -65 and +160°F are the extremes generally used to evaluate the suitability of a weapon to withstand the temperature environments. Values beyond these extremes may be encountered if particular geographic locations are to be chosen. MIL-STD-210A should be consulted for the known extremes which will occur at various world points.

3.3 Temperature and Humidity.

3.3.1 Description of Test. This test consists of exposing the explosive component to two complete 14-day JAN temperature and humidity cycles. The basic 14-day unit or "JAN TEMPERATURE AND HUMIDITY CYCLE" consists of cycling fuzes nine times between the extremes of +160°F (95 percent RH) and -65°F with additional storage at +160°F (95 percent RH) and -80°F.

3.3.2 Criteria for Passing Test. The units must be safe and operable following this test as determined by inspection.

3.3.3 Test Equipment.

3.3.3.1 The special equipment needed to run this test consists of commercially available chambers or cabinets especially made to control temperatures and humidities. It will be noted that the test cycle is so arranged that the units may be changed from one cabinet to another. Therefore if the equipment cannot be cycled between the various temperatures, the test can be run by transferring the fuzes between constant temperature cabinets.

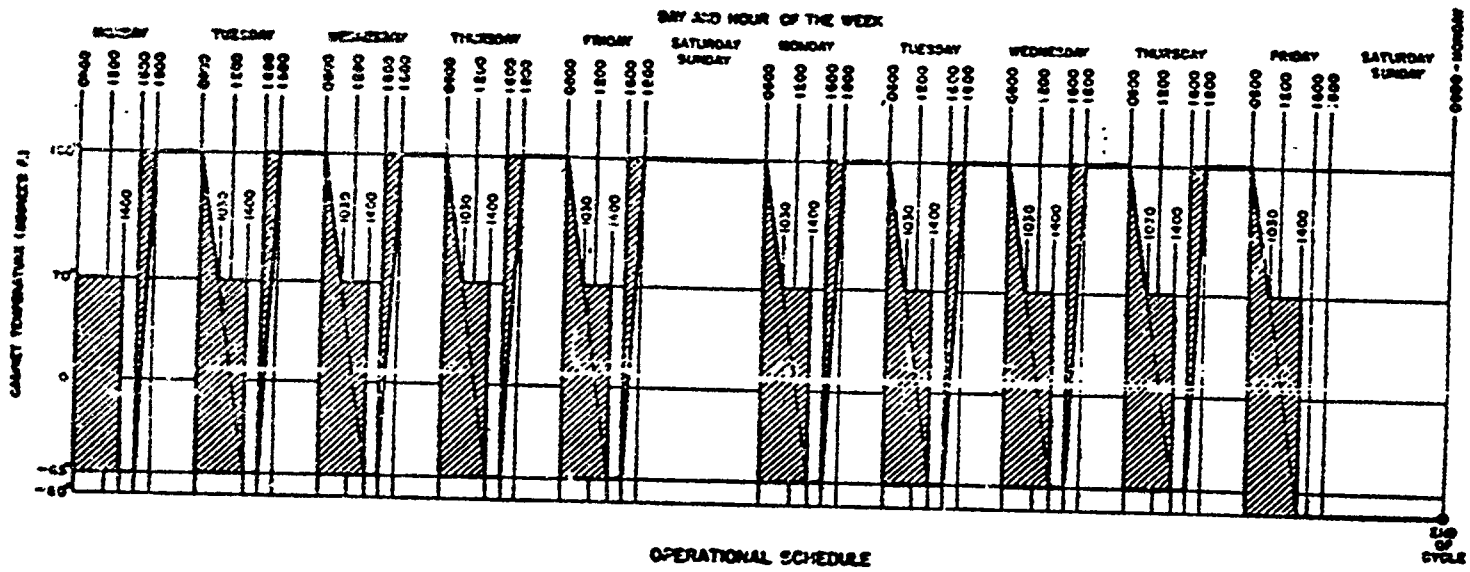
3.3.3.2 In cases where fixtures are used in the cabinets to hold the units in particular orientations, the design of the fixture shall be such that entrance of moisture will not be impeded and a minimum of interference with the attainment of thermal equilibrium will result.

3.3.3.3 The term "cabinet temperature" used throughout this test is defined as the temperature of the air immediately surrounding the test components. Cabinet temperature may thus be changed two ways: (1) by varying the temperature of a single cabinet, and (2) by moving the units from one constant-temperature cabinet to another. The fluctuations from the specified temperatures shall at no time exceed 3°F.

3.3.4 Test Procedure.

3.3.4.1 The sequence and duration of the exposure to heat and cold has been chosen so as to permit operation during a 5-day week, without overtime, and also to utilize the time from Friday at 1600 to Monday at 0800 in the sequence. For purposes of illustration, the graph shown in Fig. 4-2, and the following description, present the sequence of operations based on a start at 0800 Monday. Regardless of the day and time the test is initiated, there shall be no deviation from the sequence of operations as prescribed.

3.3.4.2 The first step is to store the units in a cabinet maintained at -65°F for at least 2 hours.



HOUR OF THE DAY	MONDAY	TUESDAY WEDNESDAY THURSDAY	FRIDAY	SATURDAY	SUNDAY	MONDAY TUESDAY WEDNESDAY THURSDAY	FRIDAY	SATURDAY	SUNDAY
			(FIRST WEEK-END)				(SECOND WEEK-END)		
0000	A	B	B	E	E	B	B	F	F
1200	A	B	B			B	B		
1400	B	B	B			B	F		
1600	C	C	C			C	F		

A - EXPOSE FUZES TO -65°F. CABINET TEMPERATURE BEFORE 1400.

B - MAINTAIN CABINET TEMPERATURE OF -65°F UNTIL 1600.

C - INCREASE TEMPERATURE OF AIR SURROUNDING FUZES TO 150°F (95% R.H.) AS RAPIDLY AS PRACTICABLE (CABINET MUST BE AT 150°F, 95% R.H. BY 1800).

D - DECREASE THE TEMPERATURE OF THE AIR SURROUNDING THE FUZES TO -65°F AT AN INITIAL RATE EQUAL TO OR GREATER THAN 36°F PER HOUR FOR THE FIRST 2½ HOURS. THE RATE MAY BE CHANGED THEREAFTER, BUT SHALL BE SUCH THAT -65°F. IS REACHED BY 1400 OR EARLIER.

E - MAINTAIN CABINET TEMPERATURE OF 160°F. (95% R.H.).

F - DECREASE TEMPERATURE OF CABINET TO -80°F. THIS TEMPERATURE TO BE MAINTAINED UNTIL THE NEXT FUZE SETTING

FIG. 4-2. JAN Temperature and Humidity Cycle.

3.3.4.3 At 1600 Monday the cabinet temperature shall be changed to +160°F (95 percent RH), as rapidly as practicable. This may be done either by removing the units from the low temperature chambers and placing them in a separate cabinet at +160°F (95 percent RH), or by changing the temperature of the chamber. The cabinet temperature must reach +160°F (95 percent RH) not later than 1800.

3.3.4.4 The units shall be held under these conditions until 0800 Tuesday, at which time the temperature decrease must begin. The rate of decrease of cabinet temperature shall be equal to or greater than 36°F per hour for at least 2 1/2 hours. Thus at 1030, the temperature of the air surrounding the units will be +70°F or lower. The cabinet temperature must reach -65°F no later than 1400, and this temperature shall be held until 1600.

3.3.4.5 At 1600 on Tuesday, the cabinet temperature shall be changed to +160°F (95 percent RH) as rapidly as practicable (not later than 1800), and held until 0800 Wednesday.

3.3.4.6 On Wednesday, Thursday, and Friday the operations carried out on Tuesday shall be repeated.

3.3.4.7 After raising the cabinet temperature to +160°F (95 percent RH) on Friday evening, these conditions shall be maintained until 0800 on the following Monday.

3.3.4.8 At 0800 Monday, the sequence of operations described above for Tuesday of the first week shall be carried out and shall be repeated daily until Friday of the second week.

3.3.4.9 On Friday the cabinet temperature shall be reduced to -80°F instead of -65°F, and this temperature shall be maintained until 0800 Monday of the third week. The cycle is completed on Monday at 0800, at which time the second cycle shall be started.

3.3.4.10 The sequence of temperature and humidity conditions described above shall constitute one JAN temperature and humidity cycle. Two such cycles shall be applied in testing fuzes. Since at 0800 Monday of the

third week the cabinet temperature will be -80°F, it will only be necessary to raise the temperature to -65°F, and the sequence of changes can be followed exactly as described above.

3.3.4.11 The second cycle is completed on Monday of the fifth week at 0800 at which time the units are allowed to return to ambient temperature (approximately 70°F).

3.3.4.12 The units shall then be examined and/or tested for conformance with paragraph 3.3.2.

3.3.5 Related Information.

A relative humidity of 95 percent at the high temperatures is used because damage to certain typical elements is accelerated in the presence of moisture. It has been found through experiment that in the case of ordinary thread seals and other similar closures, moisture is transported into the interior of units primarily through diffusion rather than by a "breathing process", although both occur. However, there have been instances where moisture entry could have occurred only during the cooling period. For instance, in one assembly utilizing an "O"-ring gasket seal, a partial relief of the pressure differences (developed during cycling) occurred, a pressure differential being maintained after attainment of thermal equilibrium. In this situation diffusion would be excluded as the process for moisture transport and moisture entry would occur only during the cooling period. Thus, the results obtained by imposing a slow cooling period with maintenance of high relative humidity, would differ from those obtained when units are allowed to cool at ambient humidity. Therefore, if a unit has such seals, the designer should consider this point in running the test.

3.4 Jolt.

3.4.1 Description of Test. This test shall consist of jolting each sample 1,750 times in each of three positions in the Jolt testing machine, as shown in MIL-STD 331 (Ordnance Corps Drawing 81-3-30). In that part of the test where the fuzes are positioned with the longitudinal axis in

a horizontal direction, the units shall be oriented so as to expose what are considered to be the most vulnerable plane or planes of weakness.

3.4.2 Criteria for Passing Test. In general, it is not required that the units be operable after this test. The criteria by which the samples are judged to have withstood this test are that (1) no elements shall explode, burn, or char and (2) no parts shall be broken, be deformed, be displaced, or come apart in such a manner as to make the assembly unsafe to handle and dispose of as determined by examination.

3.4.3 Test Equipment. The machine consists basically of a pivoted arm, the free end of which is alternately elevated to a height of 4 inches by cam action and allowed to drop freely upon a leather padded anvil. The free end of the arm is provided with three sockets into which test items can be assembled in the three required positions.

3.4.4 Test Procedure.

3.4.4.1 Check to determine that the machine is in proper operating condition, with particular attention being given to the condition of the leather pad.

3.4.4.2 Insert the units in the three available positions of the machine. Those in the horizontal position should be oriented by the use of shims so as to expose what are considered to be the most vulnerable planes of weakness.

3.4.4.3 Operate the machine through 1,750 jolts of the arm at the standard speed of 35 blows per minute.

3.4.4.4 Repeat the steps 3.4.4.2 and 3.4.4.3 twice, with the units in different positions, so that at the conclusion of the test each item will have received 1,750 jolts in each of the three positions of the machine.

3.4.4.5 Examine the units for compliance with paragraph 3.4.2.

3.4.5 Background Information. (Not a mandatory part of this test.)

3.4.5.1 The jolt test has been used for many years to establish the safety and general ruggedness of fuze designs under the application of repeated shocks in several directions. The test was originally designed as a simulation of the shocks received during transportation of Army caissons over rough terrain. In its present application the test is not intended to be accurately representative of actual conditions which may be encountered in transportation, handling or use of an explosive item. It is rather a deliberate exaggeration of severe conditions to which the item conceivably might be exposed during transportation or use. As a development test it is valuable in demonstrating the basic ruggedness of the design. Although it is not a requirement of this test that the item be operable. In such cases operability is generally judged by examination only, although firings may be conducted where considered appropriate by the designer.

3.5 Jumble.

3.5.1 Description of Test. This test consists of tumbling the unprotected sample explosive items through 3,600 revolutions in a jumble testing machine, shown in MIL-STD 331 (Ordnance Corps Drawing QEL 1386-1).

3.5.2 Criteria for Passing Test. In general, it is not required that the items be operable after this test. The criteria by which the samples are judged to have withstood this test are that (1) no elements shall explode, burn, or char, and (2) no parts shall be broken, be deformed, be displaced, or come apart in such a manner as to make the unit unsafe to handle or dispose of as determined by examination.

3.5.3 Test Equipment. The jumble machine consists of a wood-lined steel box, which is rotated about two diagonal corners of the bottom at a standard speed of 30 rpm.

3.5.4 Test Procedure.

3.5.4.1 Check to determine that the machine is in proper operating condition, with particular attention being given to the condition of the wood liner. A substantial thickness of wood should be present. One-fourth inch is considered to be a practical minimum thickness at the bottom of the worn areas.

3.5.4.2 Place one unprotected unit in the box and secure the cover, and rotate the box through 3,600 revolutions at the standard speed of 30 rpm.

3.5.4.3 Remove and inspect the item for compliance with paragraph 3.5.2.

3.5.5 Background Information. (Not a mandatory part of this test.)

3.5.5.1 The jumble test, has been used for many years to establish the safety and general ruggedness of fuze designs under the application of repeated shocks in several directions. The test was originally designed to simulate those shocks a loose fuze would receive during transportation on an Army caisson traveling over rough terrain. In its present application the test is not intended to be accurately representative of actual conditions which may be encountered in transportation handling or use of an explosive component. It is rather a deliberate exaggeration of severe conditions to which the item conceivably might be exposed during transportation or use.

3.6 Forty Foot Drop.

3.6.1 Description of Test. The test consists of a series of five drops, each employing a fresh explosive component assembly to an appropriate fixture to simulate service mounting, with each drop having a different orientation of impact. The test assembly is dropped 40 feet in free fall onto a steel plate solidly supported on a reinforced concrete base. The impact area shall be surrounded on all four sides by an enclosure of sufficient height and strength to contain the assembly during rebound. The interior horizontal dimensions of the enclosure shall be approximately the same as those of the steel plate.

3.6.2 Criteria for Passing Test. In general, it is not required that the units be operable after this test. The criteria by which the samples are judged to have withstood this test are that (1) no elements shall explode, burn or char and (2) no parts shall be broken, be deformed, be displaced or come apart in such a manner as to make the assembly unsafe to handle or dispose of as determined by examination.

3.6.3 Test Equipment. The 40-foot height necessary to perform this test can be obtained by using any tower, derrick, or boom arrangement provided the conditions of free fall and impact are met.

3.6.3.1 The impact surface shall be a steel plate having a minimum thickness of 3 inches and a minimum Brinell hardness of 207. The plate shall have a flat surface (not deformed from previous test impacts to the point where further proper angular impacts are prevented) and shall have a length and width at least 1 1/2 times the maximum dimensions of the assembly being dropped. The plate shall be solidly supported in a horizontal plane over its entire bearing area by a minimum thickness of 24 inches of reinforced concrete.

3.6.3.2 A guidance system may be employed to insure the proper angle. For example, a vertical steel tube may be used for nose or tail impacts; however, the guidance system shall be disengaged at a sufficient height above the impact plate to permit unimpeded free fall and rebound to occur. The guidance system shall not reduce the impact velocity of the item being dropped more than 2 percent of the velocity the item would achieve in 40-foot free fall.

3.6.4 Test Procedure.

3.6.4.1 In general, this test requires that each unit shall be assembled to a fixture which simulates service mounting.

3.6.4.2 One unit shall be dropped in each of the five orientations of impact as follows:

a. Longitudinal axis[1] of the test vehicle vertical with nose down.

b. Longitudinal axis of the test vehicle vertical with base down.

[1]Longitudinal axis of the test vehicle is that which is parallel to the line of flight axis of the weapon.

c. Longitudinal axis of the test vehicle horizontal.

d. Longitudinal axis of the test vehicle 45 degrees from vertical with nose down.

e. Longitudinal axis of the test vehicle 45 degrees from vertical with nose up.

The angular tolerance for each of the impacts shall be ±10 degrees. During drops other than vertical with nose down and vertical with base down, the lateral orientation of the test vehicle shall be such as to expose the most critical or vulnerable plane of the unit to impact (as determined by engineering judgment or past experience with the design).

3.6.4.3 In performing the test, the following steps are necessary:

a. An undropped unit shall be assembled to the appropriate vehicle.

b. Drop the vehicle 40 feet to impact in the chosen orientation. Velocity of impact shall be as specified in paragraph 3.6.3.2.

c. Examine the unit for conformance with paragraph 3.6.2.

d. Do not reuse this item for other drops. The test vehicle, however, may be reused if damage incurred will not affect results of other drops.

3.6.5 Background Information.

3.6.5.1 The 40-foot drop test has been used for many years in safety testing of fuzes. Although the test is not a direct simulation of field or Fleet conditions, it is a safety test which represents free fall possibilities of a projectile, bomb, missile, or other munition during handling from deck to ship, or the possibility of between-deck falls on shipboard. If other drop heights or impact media are considered possible in service use and the test item is vulnerable to these conditions, such tests should also be conducted.

3.6.5.2 It may be advisable to perform the 40-foot drop test with fuzes at extreme temperatures when materials or components are suspected of being vulnerable under these conditions.

3.6.5.3 While it is desirable to have new impact surfaces for each drop on the steel plate, it is recognized that this is not economically sound. Experience in usage of this test has shown that additional impacts on a plate can be accomplished without affecting the validity of the test. There are, however, limits of usefulness for individual plates depending upon the type of vehicle and the weight of units being tested. These would be units which would cause defects such as "dishing" of the plate and pock marking or spalling, etc., and which would reduce the anvil effect or the actual angle of contact between the drop vehicle and the plate to such an extent that the test would be invalid. Replacement of tne plate will be determined by engineering judgment.

3.7 Tactical Environment.

3.7.1 Description of Test This test consists of subjecting the samples to a series of tests designed to simulate the tactical environment of the weapon in which the explosive component is to be used. This may include captive flight vibration, missile flight vibration, shipboard vibration, thermal shock or salt spray.

3.7.2 Criteria for Passing Test. The units must be safe and operable following this test as determined by radiographic inspection and output tests.

3.7.3 Test Equipment and Procedure. As this test is directly related to the design and deployment of a particular weapon system, the test equipment and procedure cannot be specified in this document. It can only be emphasized that the test should closely simulate the worst environmental conditions that might be encountered by an explosive component in a Fleet deployed weapon.

4. SPECIFICATION REVIEW

The quality control provisions of the procurement specification must also be reviewed to determine whether they adequately define the material evaluated for qualification and will assure that the sensitivity characteristics of the explosive will continue to meet the criteria of this chapter.

CONTENTS

1. SCOPE

1.1 Purpose. This chapter establishes criteria for the selection and acceptance of main charge explosives.

1.2 Applicability. This document is to be applied as a qualification standard for main charge explosives and not as a procurement or quality control standard. It is necessary, however, that explosives qualifying under this document for the applications of paragraph 1.1, contain in their procurement specifications a sufficient number of the tests described herein to assure continued control of the properties which this document is designed to measure. When such tests are not included, the requirements of this document, at the discretion of the procuring activity, may be invoked to demonstrate that the explosive as procured still qualifies.

2. APPLICABLE DOCUMENTS (See 5.3.3.2)

MIL-P-387A	PETN.
MIL-T-00339A	Tetryl.
MIL-STD-650	Explosive, Sampling, Inspection Testing.

Other documents are listed in the reference section.

3. DEFINITIONS

3.1 Main Charge Explosive.

Main charge explosives are compounds or formulations such as TNT or Composition B which are used as the final charge in any explosive application. These explosives, because of their insensitivity, ordinarily require initiation by a booster explosive. For this document explosives do not include pyrotechnics or propellants unless they are used as the principle energy source for destructive effects.

3.2 Explosive (Material).

As used herein, the term "Explosive" or "Explosive Material" implies not only a specific composition, but a specific particle size distribution, purity, and process of manufacture. Where a specification includes several variants as indicated by types, grades, classes, etc., each permutation of type, grade, class, etc., shall be considered to be a different explosive. When foreign materials, such as binders, lubricants, etc., are added at the point of loading, each explosive material with each such additive in each proportion will be considered to be a different explosive, and each is subject to the qualification provisions of Section 5. In addition, each shall be considered to be a "new composition" for consideration as per paragraph 4.2.

3.3 Candidate Explosive.

As used herein, the term "candidate explosive" is any explosive material being evaluated in accordance with this document.

3.4 Test.

As used herein, the term "test" is the complete series of trials or replicates specified.

3.5 Trial.

The term "trial" means the application of a stimulus to a single specimen of explosive.

3.6 Representative Sample.

Sampling procedures may be varied to accommodate circumstances. However, where feasible, part of each representative sample shall be drawn from each container and from various locations within each container. The sample shall not be blended before use in tests.

3.7 Sub-Sample.

Where part of each sample, as specified above, is drawn from each container and/or from various locations within each container, each such part is considered to be a "sub-sample".

4. GENERAL REQUIREMENTS

4.1 Basic. All explosives used in main explosive charges shall have met all of the mandatory requirement given in Section 5. Each explosive material, as defined in paragraph 3.2, shall meet those requirements.

4.2 New Compositions. In addition to passing the tests prescribed in the mandatory requirements, each compound or mixture proposed for use as a main charge explosive shall be studied for the possibility of reactions with containers or contaminants or phase transitions under anticipated conditions of use. Experiments shall be performed to determine the probability of such changes and their effect upon sensitivity as determined by tests described in Section 5.

4.3 Explosive Description and Analysis. A description of what constitutes the explosive (including its composition analysis) shall be presented when applying for an interim qualification. The explosive shall be adequately defined and shall have met the requirements of this chapter.

4.4 Specimens, General Requirements. The following paragraphs and the more specific requirements for specimen preparation for specific tests under Section 5 are directed toward the preparation of specimens of each candidate explosive in a physical or chemical state similar (as is practical and compatible with test procedures) to the physical and chemical state in which the candidate explosive is to be used. Where within the latitude of the requirements as given it is necessary to exercise judgment regarding specimen preparation, this objective shall form the basis of such judgment.

4.4.1 Sub-Samples. To the extent that it is practical and feasible, sub-samples shall be kept separate, and equal numbers of specimens for each test described under Mandatory Requirements shall be drawn from each sub-sample of a candidate explosive.

4.4.2 Granular Explosives. For each test described under Mandatory Requirements, a procedure is described for the preparation of specimens from granular explosives. These procedures are applicable to pure crystalline explosives and granular explosive mixtures, including plastic

bonded explosives, which are normally formed by pressing at temperatures below the melting point of the binder and at which the binder does not undergo a chemical change (such as curing) as part of the fabrication process.

4.4.3 Cast, Molded, and Extruded Explosives. For each of the tests described in the Mandatory Requirements, the dimensions of the specimen required for each trial are given either in the test or a referenced drawing where necessary. Where the dimensions of a specimen to be used in a specific test are compatible with fabrication procedures for which the candidate explosive is intended, such procedures shall be used in specimen preparation. Where intended fabrication procedures are only feasible for charges very much larger than the specimens specified herein, these procedures shall be used to form billets of the candidate explosive from which test specimens can then be machined. Specimens for each test described shall be made from material taken at each of several locations with respect to the principal dimensions of the billets from which they are machined.

5. MANDATORY REQUIREMENTS

5.1 Impact Sensitivity.

5.1.1 Acceptable Procedures. Impact tests of 01 through 08 of The Technical Cooperation Program Manual of Sensitiveness Tests issued by TTCP Panel O-2 (Explosives) Working Group on Sensitivity, Feb. 1966 (Ref. 1) are acceptable; one of these shall be used. Procedures covering Naval Weapons Center (then NOTS), Naval Ordnance Laboratory, and Los Alamos Scientific Laboratory tests are very similar. The Bureau of Mines and UCLRL test methods are also acceptable for purposes of qualifying any non-Navy developed explosive for use by the Navy. TNT (set pt. 80.2 or better), Composition B (Grade II), and RDX are suggested calibration standards.

5.1.2 Qualification Criteria. Although the impact sensitivity test does not always correlate very well quantitatively and sometimes qualitatively with larger scale tests, a sensitivity number less than that of RDX for a formulated explosive should rule it out for consideration. This test is to be used only for a guideline; the passing criteria are not mandatory. A sensitivity number equal to or greater than that of Composition B would indicate a likely candidate for larger scale sensitivity tests. Standard explosive values should be reported together with the test explosive value determined using the same procedures. The physical form, state, and size (including whether powder or pellet) should be reported.

5.2 Large Scale Gap Sensitivity.

The large scale gap test or shock sensitivity test indicates the sensitivity of a material to shock and therefore yields useful information relating to boostering requirements, safety from sympathetic detonation while in storage, and vulnerability to air-blast weapons.

5.2.1 Acceptable Procedures. Explosive shock tests 01, 02, and 04 of Ref. 1 apply. These are Bureau of Mines, NOL/White Oak, and Los Alamos procedures respectively.

5.2.2 Qualification Criteria for Large Scale Gap Test. For use as a main charge explosive, the gap shall be no greater at the 50% probability point than the 50% value for tetryl (at 1.57 ± 0.003 g/cc). Gaps smaller than those from Composition B are preferred. The explosive must be compared using the same gap test procedure. The preparation and the processing method for the explosive shall be disclosed. The small scale gap test may give useful information when the material is limited in quantity. However, before the explosive is considered as a serious candidate for a weapon, the supply must be sufficient for large scale tests.

5.3 Friction Sensitivity.

Friction sensitivity tests are made to determine relative safety during processing.

5.3.1 Acceptable Procedures. Either of two friction sensitivity test procedures are considered adequate: The first is covered by Friction tests 01 through 03 of Ref. 1 covering Bureau of Mines, Naval Weapons Center, and Picatinny Arsenal tests. The other test is described in Ref. 2.

5.3.2 Qualification Criteria for Friction Sensitivity. Using the procedures of Ref. 1, 20/20 no fires using a standard pendulum with the steel shoe; or Ref. 2, 20/20 no fires with 250 pound force using the ABL sliding friction machine with 90 degrees pendulum drop angle and 8 ft/sec initial slider velocity shall be sufficient criteria for passing. (For the test of Ref. 1 PETN fails and tetryl passes; for the ABL method (Ref. 2) both usually pass.)

5.3.3 Other Requirements. The test shall not be considered to be valid nor shall the results be reported as part of the qualification data for the explosive under test unless the following conditions are met.

5.3.3.1 Relative Humidity. The relative humidity shall not exceed 80% as measured by a wet and dry bulb thermometer or instrument of similar reliability.

5.3.3.2 Periodic Apparatus Check. The apparatus shall be checked subsequent to or concurrent with each series of qualifying tests, by subjecting a sample of PETN (Pentaerythritol tetranitrate) per MIL-P-387A and a sample of tetryl (MIL-T-00339A) to a 50% value determination on the friction sensitivity test. Data obtained subsequent to a check test shall not be officially reported or used in the qualification of any candidate explosive until another apparatus check test has been performed. (Check test trials may be interspersed among qualification test trials in a random or systematic order so that the data can be developed concurrently.)

5.4 Electrostatic Sensitivity.

Electrostatic sensitivity tests are made to ensure relative safety from the discharge of charged objects or bodies including humans.

5.4.1 Acceptable Procedures. The Naval Weapons Center Electrostatic Sensitivity Test is designed to simulate an electrostatically charged person or object discharging through a thin layer of sample candidate material to a grounded conductive surface. A sample of approximately 50 mg is placed on a grounded steel button. A capacitor, in this case 0.02 microfarad, is charged to a selected voltage by means of a high voltage power supply. The positive side of the capacitor is then brought into contact with the sample by means of a steel phonograph needle on the end of a probe and so discharges through the sample to the steel button, which is grounded to the other side of the capacitor. The discharge is plainly visible. The test is normally conducted at a voltage of 5,000 VDC or less. An ambient temperature of 65-90°F and relative humidity not exceeding 80% are maintained. The ABL report (Ref. 2) estimates an ungrounded person can deliver a maximum discharge of 0.001 joules (0.0003μF, 3000 V). A second satisfactory test is that of the Naval Ordnance Station, Indian Head (Appendix A).

5.4.2 Criteria for Electrostatic Sensitivity. There shall be at least 20 consecutive tests of which no fires should occur at the 0.25 joule level under the foregoing test.

5.5 Vacuum Thermal Stability (VTS) 100°C.

5.5.1 Acceptable Procedures. Acceptable tests are described in Ref. 3, as corrected by the errata of 11 Jan. 1962. The test described for booster explosives (Chapter 3) is essentially the same. When an explosive is to be used at a higher temperature, values at two higher temperatures are necessary so that proper extrapolation can be made (Ref. 4).

5.5.2 Qualification Criteria. To be sufficiently stable for military storage and use, the VTS value must not be larger than 2.0 ml/g/48 hours when a 5 gram sample is used and the test conducted according to paragraph 5.5.1. When the products of decomposition are not known, as in the use of new explosive ingredients, it must first be determined whether gas evolution is sufficient criteria.

5.6 Growth and Exudation Characteristics.

When explosives contain liquids as impurities they often undergo irreversible dimensional changes when subjected to many temperature cycles between -65 and +160°F. In explosives containing TNT, the dinitrotoluenes form low-melting liquid eutectics which cause problems. Mononitrotoluenes added as anti-cracking agents give large irreversible growth in TNT explosives. In the use of pure TNT explosives, one solution to the cracking problem is the use of pure TNT with addition of high melting point eutectic formers which reduce cracking without introducing objectable irreversible dimensional change during the normal temperature variations encountered (Ref. 5). For details see paragraph 6.7.

Another cause for irreversible dimensional change is the solid-solid polymorphic transition such as occurs with ammonium nitrate. Table 5-1 gives the changes which can occur such as Beta to Gamma at 32.1°C with an increase in volume of about 3%.

TABLE 5-1. Polymorphic Forms of Crystalline NH_4NO_3.*

Form	Crystal system	Density, g/cc	Range, °C
Liquid	...	...	Above 169.6
I Epsilon (ε)	Regular (cubic) (isometric)	1.594 at 130 +5°	125.2 to 169.6
II Delta (δ)	Rhombohedral or tetragonal	1.666 at 93 +5°	84.2 to 125.2
III Gamma (γ)	Orthorhombic	1.661 at 40 +1°	32.1 to 84.2
IV Beta (β)	Orthorhombic	1.725 at 24°	-16 to 32.1
V Alpha (α)	Tetragonal	1.701 at -25 +5°	-18 to -16

*From Encyclopedia of Explosives, Vol. 1.

5.6.1 Growth and Exudation Characteristics Acceptable Procedures. Reference 7 describes the growth problem in some detail. Acceptable procedures for solids include any cylindrical sample at least 1/2-inch diameter by 1/2-inch high, temperature cycled between -65 and 140°F for 30 cycles or more. If no exudation nor excessive growth is noted on

triplicate samples, an additional test should be made for exudation by placing two cylinders together inside a sealed can. These should be held together by steel parallel face plates and clamped together to an initial pressure of 60 psi. The sealed unit is subjected to 30 cycles from ambient to 140°F, maintaining each temperature long enough for the entire sample to reach the temperature of the oven. It is then observed for exudation; any exudate is removed and weighed.

5.6.2 Qualification Criteria for Growth and Exudation Characteristics. Irreversible "growth" and exudation both cause problems in ordnance items. Irreversible dimensional change could ruin a carefully designed warhead by distorting the geometry of a lens system, by damaging the fuze well, or by causing leakage into detonator areas.

The irreversible change after 30 cycles should not be more than 1.0 volume percent as measured by calipers and calculated, or as determined by density change. Exudation should be less than 0.1% by weight.

5.7 Self Heating.

A series of laboratory tests will be run to determine the relative safety of material for self-heating under varied conditions. This should include thermal decomposition studies and selected physical property analysis on the candidate explosive. Then, when possible, kinetic or procedural kinetic parameters (frequency factors and activation energies), thermal diffusivity, heat capacity and heat of reaction will be determined so that for slab, sphere, or cylindrical configurations, the critical temperature (heat balance) and time to explosion can be predicted starting from any ambient or standard condition.

5.7.1 Acceptable Tests. Details of the procedure for determining kinetic parameters, procedural kinetic parameters and thermal diffusivity of explosives are described in Ref. 6, 7, and 8 respectively. The heat capacity and heat of reaction (or explosion) are standard laboratory tests. The procedures for calculating or predicting the critical temperature and the time to explosion are described in Ref. 7. The

experimental procedures for determining the self heating (the experimental value for the critical temperature and the time to explosion) of an explosive charge of a given mass and geometry are also described in Ref. 7.

5.7.2 Criteria for Acceptance.

Self-heating should not cause deflagration nor be detectable (< 1°F) in any normal size or shape of explosive used in bombs or warheads from ambient temperature conditions up to 165°F. The calculated critical temperature or the time to explosion for a given mass and geometry of explosive should not be less than 180°F or 500 days at this temperature. The maximum size to be considered for normal use will be 2,000 pounds. Whenever an explosive is to be used in larger quantities in any one warhead or bomb, self-heating and calculations for critical temperature and time to explosion must be considered for that size for any explosive.

5.8 Detonation Velocity.

These tests will be performed in accordance with Ref. 9 and 10.

6. BACKGROUND INFORMATION

The following tests are desirable for background information. Some of these tests may be required for either interim or final qualification depending upon the application.

6.1 Bullet Impact Sensitivity.

Although bullet impact sensitivity testing is required by NR-50 for warheads, it is covered herein for information and is not a sole cause for rejection.

6.1.1 Acceptable Procedures. The US/Fragment Impact/02 0.50 Caliber Projectile Impact Sensitivity Test used by the Explosives Research Center, Bureau of Mines, Pittsburgh, Pa. (Ref. 1) is the preferred procedure. The sample containers with flat ends may give less variation of results. US Fragment Impact Tests 01 through 04 are considered satisfactory.

6.1.2 Advisory Statement. Those explosives which do not detonate, deflagrate or burn would be considered highly desirable: those burning but not detonating would still be generally satisafactory, those detonating would be used only in applications where detonation from projectile impact is unlikely because of protection, high altitude release or other considerations.

6.2 SUSAN Sensitivity Test.

This is a test developed by the Atomic Energy Commission and has been standardized by a Tripartite Group for atomic weapons.

6.2.1 Acceptable Procedures. US/Impact/14 (Large Scale-SUSAN) (Ref. 1) as conducted at Naval Weapons Laboratory, Dahlgren and designed by the Lawrence Radiation Laboratory in 1961 is acceptable.

6.2.2 Advisory Statement. To be acceptable the explosive should indicate a sensitivity significantly lower than that of PBX 9404 in the form and density normally used for these tests. This test is not adequate in its present form for some slurry and other explosives.

6.3 Vibration Test.

Vibration tests will be conducted to provide some indication of the ability of the new explosives to withstand a dynamic environment without serious degradation or deterioration of the explosive due to powdering, physical property changes, structural failure of the explosive, etc.

6.3.1 Acceptable Procedure.

6.3.1.1 Test Samples. Test samples shall be made by using predicted liner material and explosive manufacture processes to make a sample in the test container shown in Fig. 5-1. Three samples of a given type and manufacture shall be submitted for testing.

6.3.1.2 Vibration Test Environment. The samples shall be subjected to a vibration environment of:

0.2 inches double amplitude (DA) from 5 to 14 Hz (cps)

2 g vector from 14 to 26 Hz

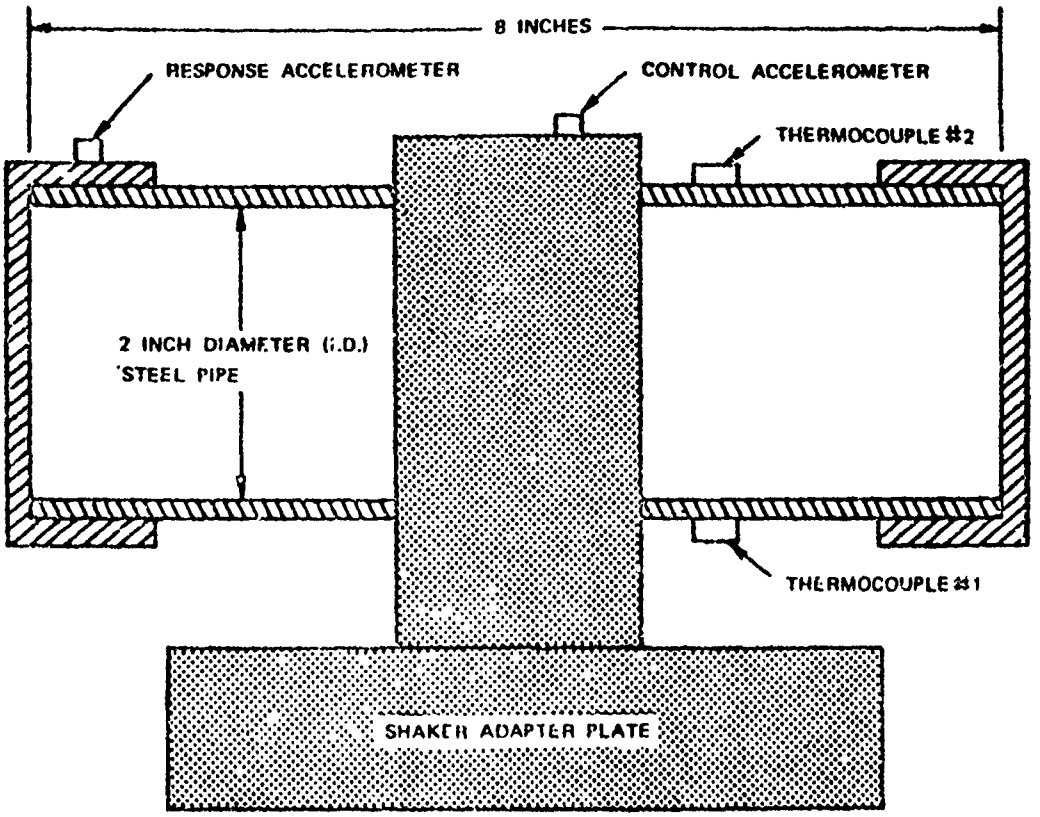


FIG. 5-1. Vibration Test Setup.

0.06 inches Double Amplitude (DA) from 26 to 37 Hz

10 g vector from 57 to 500 Hz

Sweep time from 5 to 500 Hz shall be 7 1/2 minutes for the resonant search. Resonant dwells of 30 minutes shall be conducted at the four lowest resonant frequencies. If four resonant frequencies are not present, the total test time of 2 hours shall be completed by cycling from 5 to 500 to 5 Hz in 15 minute cycles.

Tests shall be conducted in longitudinal and one transverse direction only. Total test time shall be 4 hours and 15 minutes.

6.3.1.3 Test Instrumentation. Accelerometers for control and response vibration measurement and thermocouples for temperature measurement shall be installed as shown in Fig. 5-1.

6.3.1.4 Test Temperature. Tests shall be conducted at -40 ± 4°F, +135 ± 4°F, and 77 ± 5°F. The three samples (one at each temperature) shall be subjected to the test. Minimum temperature pre-conditioning time shall be 8 hours. The temperature shall be maintained during the tests.

6.3.1.5 Failure Criteria. A catastrophic failure (detonation or burn) shall be investigated to determine mode of failure. If the failure is due solely to the explosive, it would be considered unusable. Slight deterioration or powdering shall not be considered a failure. Other failure criteria shall be determined by the particular explosive characteristics relative to the series of tests being conducted.

6.4 Drop Tests.

Since the small scale impact sensitivity tests do not reliably predict larger scale behavior, other drop tests are conducted which more closely simulate actual accidental dropping of weapons.

6.4.1 Acceptable Test Procedure. US Impact 09 through 12 (Ref. 1) covering Naval Weapons Center, NOL/White Oak, and Naval Weapons Laboratory/ Dahlgren tests are acceptable. It is not expected that more than one of these tests will be used on any one explosive.

6.4.2 Advisory Statement. These tests have in the past been performed to provide information, and decisions have been made based on comparison with other explosives. Explosives more sensitive than Composition B have been questioned, but some have been passed. The explosive can be categorized according to this test as more or less sensitive than others, and explosive selection for warhead considerations made accordingly without go-no-go criteria.

6.5 Small Scale Gap Test.

This test may be performed during preliminary evaluation of the explosive to determine particular applications of interest. The test is not required for main charge explosives; however, since the large scale gap test is considered an essential discriminatory test, it may be useful in preliminary evaluation.

6.5.1 Acceptable Procedures. Acceptable tests are US Explosive Shock 03 (Ref. 1) an NOL procedure, US Explosive Shock 06, a Naval Weapons Center procedure, and US Explosive Shock 07, a Pantex Ordnance Plant, Amarillo, Texas procedure.

6.6 Skid Tests.

A combination of friction and impact is a frequent cause of accidents where large pieces can be dropped a few feet. The skid test was originally developed by the Atomic Research Establishment in cooperation with the Explosives Research and Development Establishment, both of the United Kingdom. (This test alone has caused an explosive otherwise considered safe to be withdrawn or modified before acceptance by the University of California, Lawrence Radiation Laboratories.)

6.6.1 Acceptable Procedure. Acceptable tests are US/Friction plus Impact 01 and 02 (Ref. 1).

6.6.2 Advisory Statement. Although this is listed under background information, if conducted, a value of less than 5 feet in Test 02 giving high order detonations should disqualify an explosive. Similarly in test 01 a 50% height of less than 9 feet should be cause for rejection.

6.7 High Temperature Exposure.

The nature of this test will depend upon the expected use of the explosive. If it is expected to be used at higher than normal storage temperatures (e.g., flight at high Mach No.), the upper temperature requirement must be determined (Ref. 4).

6.7.1 Acceptable Procedures.

6.7.1.1 The procedure of WR-50 (MIL-STD 810D Test 501) (Ref. 11) shall be used except that the specimen rather than being a warhead will be a test vehicle. A 4-inch diameter by 6-inch long pipe with caps on both ends will be used. Three of these will be filled with 4 inches of explosive being careful to keep explosive out of threads. The weight and height should be determined accurately. Post test examination shall be made for irreversible growth, cracking, exudation, and any migration of explosive ingredients.

6.7.1.2 A supplementary test shall be to include three sets of two specimens, 1-inch diameter and 1-inch high, clamped together at a pressure of 60 psi. These specimens shall undergo the sample test cycle and examination for exudation. Instead of being exposed to humidity, these specimens should be placed in sealed containers so that any exudate will not be lost. Samples shall be measured and weighed accurately; and weight loss, irreversible dimensional changes, and percent of exudate determined.

6.7.1.3 An alternate procedure for determining exudation under temperature cycling exposure is the procedure used for determining exudation of a PBX during cycling to 300°F.

6.7.1.3.1 The explosive to be tested is cast into 2 inch diameter by 1 5/8 inch high charges or into aluminum cups of about the same inside dimensions, each with a cover with outside threads which can be screwed into the aluminum cup to make contact with the top of the explosive.

6.7.1.3.2 The cup dimensions are approximately as shown in Fig. 5-2. Half of the covers have 1/8 inch diameter holes in the center.

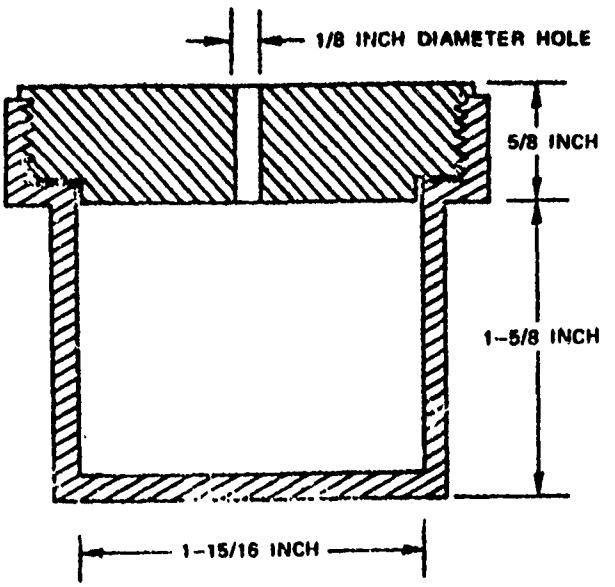


FIG. 5-2. Aluminum Cup.

6.7.1.3.3 After curing, there is a gap of less than 0.002 inches between the explosive and the aluminum container when PBXC-113 is used.

6.7.1.3.4 The charges in the containers and also the base charges are cycled to a temperature of 149°C (300°F), held at this temperature for 1 hour, and then cooled to ambient.

6.7.1.3.5 After 10 cycles, weight and dimensional changes of all samples are measured to check for possible losses and exudate.

6.7.1.3.6 The results obtained for PBXC-113 are noted in Table 3 of Ref. 4. These show that there was less weight loss on cycling for the charges in the aluminum containers than for the bare charges. Thus if pressure was exerted upon the explosive sample it did not force as much liquid out, and the inference is that the explosive does not have a tendency to exude.

NOTES

(1) This procedure has been used with only one explosive, PBXC-113, and it did not show exudation.

(2) Due to the lack of standardization of the test with a number of explosives, it must be considered somewhat qualitative.

(3) Use of this specific procedure may be misleading for an explosive with a high percentage of shrinkage on curing, since a large gap between the explosive and wall would result in less pressure buildup at the test temperature.

6.7.2 Advisory Statement. Greater than 1% weight loss for any reason (other than loss of water) or irreversible dimensional change should be cause for rejection. Greater than 0.1% exudation (other than water) is also cause for rejection. Crumbling under the temperature-humidity cycling is also grounds for rejection. If exudation and growth are not excessive and other properties are not changed excessively (see WR-50 & MilSTD 810 B Test 501, ~~paragraph~~), the explosives are considered to have passed this test series.

6.8 Compatibility With Standard Materials.

Explosives are used in proximity with various materials; it is important that the explosive not react with steel, brass, copper, aluminum, zinc, magnesium, lead, stainless steel, and malleable iron.

6.8.1 Acceptable Procedure. Reactivity test given in MIL-STD-650 under 504.1.

6.8.2 Advistory Criteria for Compatibility from Reactivity Tests. The mixture should show no enhancement in gas evolution as described in MIL-STD-650.

6.9 Physical Stability.

The explosive should maintain its integrity throughout the normal usage temperature range (-65 to 160°F) (Ref. 12 and 13). That is, it should neither be segregated by standing (or from being vibrated) at an elevated temperature nor be changed in physical phase such that a large volume expansion occurs.

6.9.1 Acceptable Procedure. Exudation and irreversible dimensional change were covered under paragraphs 5.6 and 6.7. To observe whether segregation occurs, analysis of sections of the explosive must be made when the material has been partially liquid at any time.

6.9.2 Criteria for Acceptance. A composition spread of more than 4% of one ingredient from top to bottom of an explosive charge (not specifically designed that way for an application) should be considered excessive.

6.10 Physical Properties.

6.10.1 Melting Point. This is a simple determination and any method where a suitable calibration standard is used in the range of the melting point of the compound or mixture involved is considered suitable.

6.10.1.1 Procedures. One acceptable procedure is as described on page 19 of (Ref. 3). Another acceptable procedure is "Melting Point of Semi-Crystalline Polymers", ASTM D2117-64(27) 1968.

6.10.1.2 Criteria for Melting Point. For a conventional solid explosive, there should be no melting of ingredients below 60°C (140°F). The preferred solid explosives melting point would be above 72°C (160°F).

6.10.2 Softening Point.

6.10.2.1 Acceptable Procedure. ASTM D1525 (27) p. 525 (1968). The softening point can be used where non-crystalline or non-melting components are present.

6.10.2.2 Criteria for Softening Point. No softening of a material should occur below 60°C (140°F).

6.11 Physical Properties at Various Temperatures.

Within the temperature range of normal use (unless otherwise specified -65 to +160°F), the material should not undergo undesirable changes in properties. A phase change that caused the material to undergo liquifaction would be unsuitable if a design incorporating the use of an explosive did not allow for use of liquids. If physical strength such as compressive and tensile are made use of in subsequent applications, a large degradation of strength on heating could lead to a design failure. A solid polymorphic transition could also lead to undesirable properties.

6.11.1 Acceptable Procedures. ASTM or other recognized standards are sufficient for physical strength tests. Compressive and tensile strength and modulus of elasticity are often useful measurements (see paragraphs 6.15 through 6.24).

6.11.2 Advisory Statement. Unless certain properties are called for in applications considered, this need not be considered for acceptance, however gross reduction in physical, tensile, and compression strength should be cause to question the use of the explosive. A 100% or more reduction in modulus might indicate a phase change with attendant possible exudation.

6.12 Toxicity.

It is important that relatively non-toxic materials be used whenever possible both to prevent hazard to health in processing plants, and potential hazard during storage and handling should breakage or corrosion leaks occur.

6.12.1 Acceptable Procedure. New and untested materials should be tested for toxicity. NAVMAT INST 5100.3 MAT 046 July 17, 1969 will be followed in investigating and controlling hazardous materials which are not explosive but which may be ingredients in explosives formulations. For explosive materials SECNAV 6270.2A shall be followed. A letter will be processed via Industrial Hygienist of the activity concerned to BuMed

Code 73. The Bureau of Medicine and Surgery in turn reports to the Council who determines whether a toxicity study should be made. Some activities have other routines which are working satisfactorily.

6.12.2 Criteria for Acceptance. This is determined by the Occupational Health Division of the Bureau of Medicine and Surgery.

The duPont Company has estimated that a full toxicity study on one of their new products costs them about one million dollars.

6.13 Radiation Effects.

Knowledge of the effects of radiation (X-ray, γ-rays, and neutrons) may be desirable for new explosives.

6.13.1 Acceptable Procedure. The procedure of Ref. 14 is tentatively suggested in lieu of a standardized procedure. In addition ASTM D1672-66 (27) P553 (1968) Exposure of Polymeric Materials to High Energy Radiation provides information on exposure, especially of polymer binders to radiation.

6.14 Effect of Exposure to Moisture.

The results obtained in the presence of moisture should be known. This can be obtained during other tests such as those for growth and exudation. Moisture on aluminized explosives particularly during processing can cause fire, for example, while being oven dried, when non passivated aluminum is used.

6.15 Coefficient of Thermal Expansion.

6.15.1 Acceptance Procedures. Coefficient of linear thermal expansion of plastics ASTM D696-(27) 1968 and Coefficient of Cubical Thermal Expansion of Plastics ASTM D 814-52 (27) 1968.

6.16 Thermal Conductivity.

6.16.1 Acceptable Procedures. Test for thermal conductivity of materials by means of the guarded hot plate ASTM C-177 (27) 1968. Also, plastics-General Methods of Testing, Nomenclature ASTM D2326-64T (25) p 483 (1968) includes another conductivity measurement.

6.17 Flexural Strength.

6.17.1 Acceptable Procedures. Flexural Properties of Plastics ASTM D790-66 (27) p 302 (1968).

6.18 Modulus.

6.18.1 Acceptable Procedure. Included under compressive properties in ASTM D 695-63T (27) p 249 (1968).

6.19 Hardness.

6.19.1 Acceptable Procedure. Rockwell Hardness of Plastics and Electrical Insulatory Materials ASTM D785-65(27) (1968).

6.20 Compressive Strength.

6.20.1 Acceptable Procedure. ASTM D695-63T (27) p 248 (1968). This document includes compressive stress, compressive strength, compressive strength at failure, compressive deformation, compressive strain, compressive yield point, yield strength, modulus of elasticity and crushing load.

6.21 Tensile Strength.

6.21.1 Acceptable Procedure. ASTM D638(27) p 189 (1968). This includes tensile strength, percent elongation, rate of stressing, and elastic modulus.

6.22 Impact Resistance.

6.22.1 Acceptable Procedure. Impact Resistance of Plastics at Subnormal and Supernormal Temperatures ASTM D 758 (27) p 290 (1968).

6.23 Stiffness.

6.23.1 Acceptable Procedure. Stiffness of Plastics by means of a Cantilever Beam, ASTM D 747-63 (27) p 272 (1968).

6.24 Deformation Under Load.

6.24.1 Acceptable Procedure. Deformation of Plastics Under Load, ASTM D621-64 (27) p 175 (1968). This is a useful test to aid in determining flow properties and compressibility.

6.25 Bulk Density.

It is important to know the bulk density of an explosive both for a solid warhead or bomb explosive and for explosive powders that are to be pressed.

6.25.1 Acceptable Procedures. The procedure of 4.6.7 of WS 3824 (Ref. 15) applies. Place approximately 50 grams (weighed to nearest 0.1 gram) of the sample material from the composite sample (as described under 4.3.1 of WS 3824) into a 100 ml cylinder (graduated in 1 ml increments). Compact the material by allowing the cylinder fall freely from a height of 1-inch onto a 1/4-inch-thick felt pad meeting requirements of Specification C-F-206, Type I, Class 16R3. After the sample material has been compacted 50 times, read the volume of material in the cylinder to the nearest ml.

$$\text{Bulk density: gm/ml} = \frac{W}{V}$$

where

W = weight of sample in grams
V = volume compacted material in ml.

6.25.2 Another acceptable procedures is Apparent Density, Bulk Factor and Pourability of Plastic Materials ASTM D 1895-67 (27) p 604 (1968).

6.26 Shrinkage on Cure.

6.26.1 Acceptable Procedure. Linear Shrinkage of Thermosetting Casting Systems During Cure. ASTM D 2566-66T (26) p 727 (1968).

6.27 Flow and Injection Moldability.

6.27.1 Acceptable Procedure. Injection Molding of Specimens of Thermoplastic Molding and Extrusion Materials, ASTM D1897-68 (27) p 613 (1968).

6.28 Adiabatic Sensitivity Test.

6.28.1 Acceptable Procedures. A satisfactory test is that of the Naval Weapons Station, Yorktown, Va. (Appendix B).

6.29 Thermal Detonability Test.

The explosive detonability test measures the type of fragmentation produced under controlled conditions. From this it can be determined whether a detonation or merely a deflagration has occurred. The test forms an inter-correlation to the existing enveloping flame test as described in WR-50, where the time-temperature history of both tests are in the same region.

6.29.1 Acceptable Tests. Details of this test are described in Ref. 7 and 16.

6.29.2 Criteria for Acceptance. Those explosives which do not detonate in this test but burn slowly without transformation to detonation would be considered highly desirable. Those that only deflagrate rapidly but do not detonate under the test may be acceptable.

6.30 Composition Analysis.

A composition analysis procedure should be available before the explosive is considered for weapon application. Each procedure will have to be determined according to the ingredients and their properties and the methods necessary for their separation and determination.

6.30.1 Acceptable Procedure. Any procedure that gives ingredient analsis sufficiently close for practical evaluation (usually from ± 0.1 to ± 0.2 of the true value) will be satisfactory. This varies according to the type of composition and actual ingredients.

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7. PERFORMANCE

Explosive performance is considered separately from essential tests and background information because some performance methods will be considered essential for some applications and others for different applications. The performance of an explosive in a given weapon is determined through a number of warhead tests such as fragmentation with recovery of fragments, damage to specific targets, and pressure measurements.

In order to decide to which applications particular new explosives should be applied, it is necessary to determine values relating to particular modes of energy delivery (i.e., fragments, air-blast, shaped charge, etc.). Calculations and past experience serve as general guides toward synthesizing and formulating explosives with sufficient potential energy and release-rate-level to be undertaken for development. Calculations, while providing information for initial selection, must be backed up by actual performance data before selection is made to use the explosive in a given application. If the initial objective for an explosive is to increase energy of a fragmenting warhead, for example, tests which give results correlating well with fragmenting warheads are desired. Gurney values for explosives have been used to predict fragment accelerating capability in non-nuclear warheads. In nuclear warheads, hydrodynamic codes together with determined explosives parameters such as Chapman Jouget pressure, detonation temperature and others are used. Experimental methods that scale well are preferred for performance evaluation. Of all the means for predicting either fragment acceleration or metal movement for nuclear or non-nuclear warheads, the cylinder expansion method is considered the best.

A condensation (Table 5-2) has been made of the performance evaluation methods which appear useful for explosives considering the applications for which this information is needed.

TABLE 5-2. Performance Evaluation of Explosives.

Application	Test method										
	Detonation velocity for ∞ diameter	Fragment velocity	Gurney constant	Fragment mass distribution	Pressure versus scaled distance	Impulse versus scaled distance	Cylinder expansion	Chapman Jouget pressure	Shaped charge penetration	W. E. (weight for same shock as 1-lb Pentolite)	M. B. E. (Mechanical Bubble Energy)
Bombs	+	+	+	+	+	+	+	+	-	-	-
Shaped charge	+	-	-	-	-	-	+	+	+	-	-
Small caliber shells (to 40mm)	+	+	+	+	+	+	+	+	-	-	-
Large caliber shells	+	+	+	+	+	+	+	+	-	-	-
Torpedoes	+	-	-	-	-	-	-	-	-	+	+
Depth charge	+	-	-	-	-	-	-	-	-	+	+
Mines	+	-	-	-	-	-	-	-	-	+	+
Blast	+	-	-	-	+	+	-	-	-	-	-
Focussed blast	+	-	-	-	+	+	-	+	-	-	-
Continuous Rod W/H	+	+	+	+	+	+	+	+	-	-	-
Fragmenting W/H	+	+	+	+	+	+	+	+	-	-	-
Bomblets	+	+	+	+	-	-	-	-	-	-	-
Polygon charge	+	+	+	+	+	+	+	+	-	-	-
Destruct system	+	-	-	-	-	-	+	+	-	-	-

+ desirable.
- not needed.

7.1 Determination of Critical Diameter.

In his discussion of the effect of charge diameter on the detonation velocity of cylindrical charges, Taylor (Ref. 1) states:

> "These results show that the maximum or hydrodynamic velocity of detonation is approached as the diameter is increased, but as the diameter is reduced the velocity falls. Eventually the velocity becomes so low that the detonation wave is not strong enough to maintain its own propagation. There is, therefore, a critical minimum diameter for any explosive below which a self-sustained detonation wave will not propagate."

This critical diameter (d_c) defines the threshold for propagation of steady-state conditions. Because it is a failure threshold, it is far more easily affected by small variations in the physical properties of the charge than is the value of the detonation velocity at larger diameters. Consequently, charges must be of good quality if reproducible results are to be obtained. Charge preparation recommendations of paragraph 7.2 should be used.

As an explosive approaches its d_c, its shock sensitivity decreases rapidly. Hence, it is important to specify a powerful booster (e.g., CH-6, 9404) for these tests. Any irregularity of the charge such as continuous wires or metal probes are apt to perturb the threshold conditions. Hence, optical measurements with the smear camera are recommended. For a steady detonation, the streak is straight; for a failing detonation the streak is curved, and may disappear altogether. In fact, some of the unreacted explosive may be recovered after the shot. It is not necessary to determine the instantaneous velocity of the detonation from the curved traces. The observation that the trace is definitely curved in the direction of decreasing velocity is sufficient to show that the test diameter is $< d_c$. This avoids the necessity of differentiation of experimental data. It is important to have a sufficiently long charge because as d approaches d_c from below, the shock induced reaction may run for long distances at apparently constant velocity before failure can be seen (Ref. 2).

The most direct method of determining d_c is to fire a series of different diameter charges and obtain the smear-camera record of each. For castable materials which can be easily prepared as conical charges, the record of the reaction initiated at the cone's base will show failure at some diameter of the cone. This measured d_c is always too small, because in a base initiated conical charge the detonation is overboostered as it progresses to smaller diameters. The use of a stepped cylinder, instead of a cone, avoids this problem but introduces others. The length at each diameter (each step) must be about 4 d or greater to allow the overboostering to fade out and a sufficient length of steady state propagation to measure detonation velocity (D). The camera cannot view an extremely long charge and still give a record that can yield an accurate value of D. Hence, the stepped cylinder, like the cone, is best suited for obtaining a preliminary and approximate value of d_c. It should be followed by more precise measurements on cylindrical charges.

Another approximate method was used by Smith (Ref. 3) who observed the dents produced in steel plates by charges of different diameters. This method depends on an approximate measurement of total "output" and does not establish the existence of a steady-state detonation. It may, however, give a good estimate of d_c, and it can be applied to confined charges (as can also the probe method of measuring D). Up to this point only bare unconfined charges have been considered because the theory of confinement is not quantitative. For practical problems it is, of course, possible to work with a scaled confinement, i.e., constant ratio of wall thickness/internal diameter.

The range in d_c over all explosives is very large. Common pressed HE have d_c of ~1 cm or less whereas voidless composite propellants may exhibit d_c of ~several meters. For the materials with a very small d_c, it is sometimes easier to prepare a rectangular plate charge (or even a wedge) than to prepare a cylinder. In such cases, a critical height (instead of d_c) is measured and may be related to a corresponding d_c (Ref. 4). For charges of very large d_c, strong confinement is sometimes used to reduce charge size.

7.2 Determination of Infinite Diameter Detonation Velocity.

Detonation velocity (D) is the most easily measured of the detonation parameters. Its value is highly dependent on the loading density (ρ_c) of the charge and somewhat dependent on charge diameter and, for granular charges, on the initial particle size of the explosive. The hydrodynamic theory of detonation includes the density effect but not the diameter effect. Hence, it is the detonation velocity which would be observed in an infinite diameter cylindrical charge (D_i) that is necessary in any comparison of experimental results with the theory.

The usual method of obtaining D_i is to fire a series of charges of different diameters (d), and measure the corresponding D. A plot of D versus d generally shows D increasing with d and apparently approaching the value D_i asymptotically as $d \to \infty$. However, it is difficult to select D_i from such a curve, and it is more customary to plot D versus d^{-1} or D^{-2} versus d^{-2} (see Ref. 1) in a range of values of d large enough to give a linear curve. D_i is then taken from the intercept at $d^{-1} = 0$ or $d^{-2} = 0$. The plot D versus d^{-1} is most commonly used and seems most successful in exhibiting linearity at large values of d.

Because a number of charges must be used in determining the value of D_i for a single explosive in a given physical condition, charge preparation is a problem. For good results, all charges should be prepared from one uniform batch of the explosive. If the charges are pressed, isostatic pressing is recommended in preference to ram pressing (Ref. 5). This method requires machining the pressings to make cylinders of the required dimensions. If the material is cast from a melt, conditions must be carefully controlled to insure that all charges have the same physical properties (e.g., the same density and the same crystal structure. Hence, charges of different diameters and length must be prepared under carefully controlled conditions in order to determine the true value of D_i. Diameters of the charges should be chosen so that the resulting data are most useful in the extrapolation to D_i. That is, if d^{-1} is chosen as the independent variable for plotting the results, the data points should be more or less equally spaced with respect to the d^{-1} axis.

The booster explosive should have a shock impedance about 20-30% greater than that of the test explosive so that detonation is initiated reliably. Because of the mismatch of the explosives, the test charges must be long enough so that the effects of over boostering will die out by the time the detonation reaches the portion of the charge where the detonation velocity is to be measured. That is, the measured D should be that for steady state detonation. The length of charge required for this is conveniently expressed in terms of the ratio of the length of the charge to its diameter, ℓ/d, and is probably adequate when $\ell/d \geq 2$ (see Ref. 3). If the explosive has a front of constant curvature, this distance will also be sufficient for its establishment. If, on the other hand, the explosive has a front showing spherical expansion, an $\ell/d \geq 9$ should be attained for 1% accuracy (Ref. 6). In such a case, use of a plane wave booster can reduce the required length of run before measurement.

Detonation velocity can be determined in any of several ways; the choice of a method probably depends more on the availability of equipment and well tested procedures than on any inherent advantage of a given method. Some of these methods are discused by Taylor in Ref. 1.

7.2.1 Chronographic Method. The chronographic method is widely used; it depends on the closing of "switches" either by the conduction of hot gases between two electrodes, or the forcing together of two electrodes by the pressure induced by the detonation. Precision of the measurements depends on the number of switches or pins that are used on the charge, and on the precision of the equipment. Precautions which should be observed are discussed in Ref. 7.

7.2.2 Electronic Method. Another method, which is also entirely electronic, depends on embedding a resistance wire in the explosive (Ref. 8). A constant current is maintained in the resistance wire and the return path, which may be a nearby embedded copper wire, a wire or foil on the surface of the charge, or a metal case if the charge is confined. The voltage across the resistance wire is recorded on an oscilloscope. This

voltage decreases as the detonation moves along the wire and effectively shortens the wire. This method gives, in effect, the instantaneous position of the detonation front, so that the slope of the trace on the record from the oscilloscope is proportional to the detonation velocity. A closely related technique uses a resistance wire which is wound on an insulated wire or other conducting core (Ref. 9 and 10). These methods are not recommended for pressed charges. The precision of either version of the resistance technique depends on the quality of the charges, the precision of making the probes and the precision of the electronics. For small diameter charges, the probes and wires may perturb the detonation front so that a true value of the detonation velocity can not be obtained.

7.2.3 Optical Method. A commonly used optical method makes use of the streak or smear camera to record the instantaneous position of the detonation front. This method is also discussed by Taylor, who gives a picture of the "streak" for a typical explosive. Because the record gives the instantaneous location of the detonation front, the slope of the streak is proportional to the velocity. Simple data reduction techniques can be used for the application discussed here. The traces are straight so that after digitizing, the data are fitted with a linear relation, the coefficient of the time being the velocity of the detonation. Again, this method can be made to give precise results if sufficient care is taken in preparing the charges and in arranging the experiment. A description of smear camera techniques is given in Ref. 11 and the use of a 70mm smear camera with a writing speed up to 4mm/μsec is described in Ref. 12. Reference 13 discusses a number of other optical methods used in shock measurements.

7.3 Fragment Velocity.

In addition to the cylinder expansion test, described separately, an NOL cylinder fragmentation test is described in Ref. 14 and 15, and shown below.

7.3.1 Cylinder Fragmentation Test.

7.3.1.1 The comparative ability of explosives to fragment metal can be determined from the cylinder fragmentation test. The test arrangement is shown in Fig. 1 of Ref. 14.

7.3.1.2 The cylinders, 9.00 inches long, are made of AISI 1045 seamless steel tubing, cold rolled, stress relief annealed. The hardness is Rockwell B-100. The cylinders are 2.000 inches in inside diameter with a wall thickness of 0.25 inch. The wall thickness variation should be no more than ± 2%.

7.3.1.3 For cast explosives, the casting is done directly into the cylinders; for pressed explosives, the explosives are pelleted at 16,000 psi, into 1-inch-long pellets from 5 to 10 mils less in diameter than the inside diameter of the tubing. The pellets are then slipped into the cylinder making good contact with each other, but are not reconsolidated. The explosive should completely fill the test cylinder.

7.3.1.4 The mean density of the explosive must be determined. For cast explosives, this is determined from the mass of the explosive and the volume of the cylinder; for the pressed explosive, from the mass and volume of the individual pellets.

7.3.1.5 The cylinder containing the test explosive is initiated by a pressed tetryl pellet 2 inches in diameter and 1 inch long. The pellet is pressed at 10,000 psi. The pellet is initiated by an Engineer's Special Blasting cap centered by a wooden disc with an axial hole. The tetryl, wood disc, and blasting cap are held in position by masking tape.

7.3.1.6 The cylinders are positioned on end in the center of a cardboard box 12 by 12 by 12 inches. They must be in this position when fired. The cylinders are then lowered into a sawdust pit roughly 6 feet in diameter and 6 feet deep, which contains 3 feet of sawdust. When the box is positioned as desired, the remainder of the pit is filled with sawdust and the charge fired. The sawdust containing the fragments is then sent to a magnetic separator and the metal particles collected for weighing and counting.

7.3.1.7 The fragments collected from the sawdust (~98% of the original cylinder weight) are classified into 0.5 gram groupings starting at the 0.5 to 1.0 gram class. The number of fragments in each group is counted.

7.3.1.8 To analyze the data, a Mott Distribution is assumed and, thus, the logarithm of the number of fragments of mass (m) or greater is plotted against $m^{1/2}$. The Mott distribution is:

$$N(m) = N_0 \exp -\left(\frac{m}{\mu}\right)^{1/2}$$

Where N(m) is the number of fragments whose mass is equal to or greater than m. N_0 and μ are constants dependent upon the cylinder and the explosive. N_0 is the total number of fragments from the cylinder and 2N is the mean fragment mass. Large values of N_0 and small values of $\mu^{1/2}$ are obtained from the best straight lines fitted to the graph described above.

7.3.2 Cylinder Expansion. The cylinder expansion evaluation method is included as Appendix C. The method correlates well with the AEC methods from which it originates.

7.4 Fuel Air Explosives Performance.

The procedure for evaluation of the pressure and impulse from a fuel-air detonation is included as Appendix D.

7.5 Gurney Constant (See Also Cylinder Expansion).

The Gurney constant α or $\sqrt{2E}$ is obtained from the cylinder expansion evaluation of explosives. For more detailed procedure, Appendix C covers an acceptable method for Gurney constant.

It can also be obtained by solving from known values of fragment velocities using various warheads or models from the equation

$$V = \sqrt{2L}\left(\frac{C/M}{1 + 0.5\ C/M}\right)$$

where V is the highest velocity to which the particular explosive charge accelerates metal, C/M is the explosive charge weight to total case + explosive weight and $\sqrt{2E}$, related to explosive energy, has dimensions of velocity.

7.6 Detonation Pressure (Chapman-Jouget Pressure).

Detonation pressure data are derived from measurements of shock waves transmitted into water by the detonation of cylindrical explosive charges 2 inches in diameter and 6 inches long initiated by Pentolite-Baratol plane wave boosters (Ref. 16 through 22). (Also see Cylinder Expansion.)

7.7 Shaped Charge Penetration.

Shaped charge penetration depends on a large number of factors; therefore, it is imperative that any comparison be made using identical procedures. Although it is not the intent of this document to be restrictive to only one procedure, a procedure that is documented is given in Ref. 23.

7.8 Pressure Versus Scaled Distance.

Free Air Peak Overpressure Versus Scaled Distance at Various Altitudes is covered by nomograph in Ref. 24.

The overpressure scaling information was predicted previously by Sachs' scaling laws in NAVORD Report 2482 (Ref. 25). S. Brinkley in OSRD-5481 (Ref. 26) has derived the theory covering the sea-level pressure-distance curve. E. Fisher (Ref. 27) and Weibull (Ref. 28) (BRL-X-127) substantiated the curve by experimental work.

7.9 Impulse Versus Scaled Distance.

The impulse, or the area under the pressure-time curve is an important performance parameter for certain applications. Reference 24 tabulates positive impulse of shock wave versus distance and weight of explosive for bare spherical charges of TNT in air. Positive impulse for explosives other than TNT are found by determining the TNT equivalent and then using the nomograph of Ref. 24. (Other references are 29 and 30.)

7.10 Underwater Evaluation of Explosive Compositions.

In the initial evaluation of a new explosive, small (~1-lb) charges are fired and values of shock wave and bubble energies determined relative to a standard, usually Pentolite or HBX-1. Shock wave energies are measured by use of diaphragm gages, which have deflections directly related to this parameter. The equivalent weight, or W_{Dd}, is determined by comparison of the deflection caused by the experimental charge with those produced by several weights of the standard explosive. Appropriate booster corrections are made for all charges. Details of the gage and its use are given in Ref. 31, 32, and 33.

Relative bubble energy, or RBE, is defined as

$$RBE = \left(\frac{K_x}{K_s}\right)^3$$

where

K = bubble period coefficient for the experimental (x) or standard (s) charge.

The period coefficient, K, is defined in Ref. 34. Corrections for the booster charge and for the proximity of the surface and bottom are given in Ref. 33 for small charges.

For those compositions showing promise, larger charges (~10 to 100 lb) are fired and piezoelectric gages used to measure the various shock wave parameters (peak pressure, time constant, impulse, and energy). Various methods of expressing these parameters relative to a standard are employed, depending on the desired use. These include equal weight and equal volume ratios as well as equivalent weights. These methods are described in detail in Ref. 35. The data are also used to develop similitude equations for use in predicting values of these parameters as functions of composition, charge weight, and range (Ref. 36).

The free water parameters by themselves are not sufficient to establish the underwater damaging capability of an explosive. Shock wave energy is often used for this purpose; however, in actuality this damaging capability depends on the particular damage mechanism employed. Reference 37 contains an excellent discussion of this. This aspect should be investigated before an explosive is finally designated for use in an underwater weapon.

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CONTENTS

1. QUALIFICATION TESTS

Main charge explosives are given final qualification tests and final qualification only as used in their applications. The tests to be used for warhead explosives are those outlined in WR-50[1]. Tests to be performed on non-warhead explosives, such as sheet explosives, will be worked out in conjunction with the appropriate Command on a per case basis. For the warhead explosives, the latest official revision of WR-50 will be used. It will be necessary for personnel responsible for explosives development to monitor the WR-50 tests to the extent that the explosives are examined after the tests to insure that they are still safe.

2. OTHER PROCEDURES

It is necessary that an explosive, to qualify under these procedures, contain in its procurement specifications sufficient of the tests described in Chapter V to assure continued control of all parameters for which mandatory tests and suggested pass-fail criteria have been established. In addition, the following are tests which, depending on the weapon configuration or service application of the explosive, may be required by the Naval Ordnance Systems Command.

2.1 Sympathetic Detonation.

For final qualification of an explosive in a weapon or other application, appropriate sympathetic detonation tests shall be run to insure that accidental detonation of one item will not inadvertently cause other items to detonate or explode violently. A test of this nature will be arrived at as a result of an analysis of the hazard which would normally be present when items are detonated in the proximity normal to the application.

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[1] Naval Ordnance Systems Command. Naval Weapons Requirements Warhead Safety Tests, Minimum for Air, Surface and Underwater Launched Weapons, 13 February 1964.

2.2 Aerodynamic Heating.

This test will be conducted in accordance with paragraph 4.3 of WR-50.

2.3 Safe Jettison (Aircraft).

This test will be conducted in accordance with Test 201 of MIL-STD-331[2].

2.4 Drop on Studs.

This test will be conducted in accordance with paragraph 4.3 of WR-50.

2.5 Drop on Angle Iron.

This test will be conducted in accordance with paragraph 4.3 of WR-50.

2.6 Accidental Release (Aircraft).

This test will be conducted in accordance with paragraph 4.3 of WR-50 (Separation from Aircraft) and Test 206 of MIL-STD-331.

2.7 Vibration at Low Temperature.

This test will be conducted in accordance with paragraph 6.3 of Chapter V except the explosive will be loaded in the weapon configuration instead of a test container.

2.8 Forty Foot Drop at High Temperature.

This test will be conducted in accordance with paragraph 5.1.4 of WR-50 except the weapon will be temperature conditioned to 165°F prior to test.

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[2]Fuze and Fuze Components, Environmental and Performance Tests for. 10 January 1966, Notice 3, 11 June 1969.

2.9 Aerial Release (Hard Target).

This test will be conducted in accordance with Test 204 of MIL-STD-331.

2.10 Proof Pressure Firing.

The explosive shall be loaded into projectiles by the same process as used for service loading. The projectiles will be fuzed with inert components and fired at the proof pressure for the type gun under consideration. Proof pressure will be established by firing inert projectiles and adjusting the propelling charge until that pressure is attained; then the sample projectiles will be fired. Chamber pressure will be monitored by copper crusher type gages and adjusted as necessary to maintain the "proof" pressure.

The firings may be conducted in a barrel with any percent wear, but generally the desired pressure cannot be attained in a barrel worn beyond 50 percent.

At least 100 rounds of the sample shall be fired for guns larger than 5 inches. For projectiles of 5 inches or less, 100 rounds will be the minimum requirement; however, consideration should be given to firing larger quantities because such ammunition is used in much larger quantities.

None of the test projectiles shall undergo reaction in-bore or during flight. It is recognized that some of these projectiles may react at impact upon termination of the flight.

2.11 Plate Penetration.

This test will be conducted in accordance with Section III of the JMEM[3] on high explosive bombs and bomblets.

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[3]Joint Munitions Effectiveness Manual. Air-to-Surface Joint Service Test Procedures for High Explosive Bombs and Bomblets, 4 December 1968. (NAVAIR 00-130-ASR-2-1.)

2.12 Booster Performance.

This test will be conducted in accordance with Section III of the JMEM on high explosive bombs and bomblets.

2.13 Cratering.

This test will be conducted in accordance with Section V of the JMEM on high explosive bombs and bomblets.

2.14 Arena.

This test will be conducted in accordnace with Section II of the JMEM on high explosive bombs and bomblets.

2.15 Sled Track Impact.

This test will be conducted in accordance with Section III of the JMEM on high explosive bombs and bomblets.

2.16 Fragmentation.

This test will be conducted in accordance with Section II of the JMEM on high explosive bombs and bomblets.

2.17 Qualification of Explosives for Projectiles 3 Inches and Over.

Additional qualification tests for explosives used in projectiles of 3-inch diameter and over will be required. Figure 6-1 shows a typical test sequence for projectile fill certification tests. Test plans and procedures will be developed for individual requirements and approved by the Naval Ordnance Systems Command.

3. PROCESSABILITY CERTIFICATION

Prior to service acceptance of any new explosive compounds or compositions, processability studies shall be conducted and a certification made to the effect that the compound can be processed in a safe manner and with a high assurance that the quality levels required for the intended weapon design can be met with reasonable economical considerations.

Full scale candidate explosive compound preparation and loading of weapons shall be used for justification of the certification. Sufficient different batches of the raw ingredients shall be processed to insure the compound's producibility from mass produced raw materials.

Safety and environmental tests shall be conducted on full scale weapons loaded with the candidate explosive and processed in the same manner and to the same specification as that proposed for production. The explosive batch size, number of batches, and number of weapons required to be loaded for certification will be determined for each weapon based upon the complexity of compounding, weapon design factors, and proposed production notes.

4. SPECIFICATION REVIEW

The quality control provisions of the procurement specification must also be reviewed to determine whether they adequately define the material evaluated for qualification and will assure that the sensitivity characteristics of the explosive will continue to meet the criteria of this document.

The final qualification document should be submitted to the appropriate Command with a request for release for service use. It should also contain a compilation of the interim qualification data or sufficient comparable test data on production material so that the Command can take positive action.

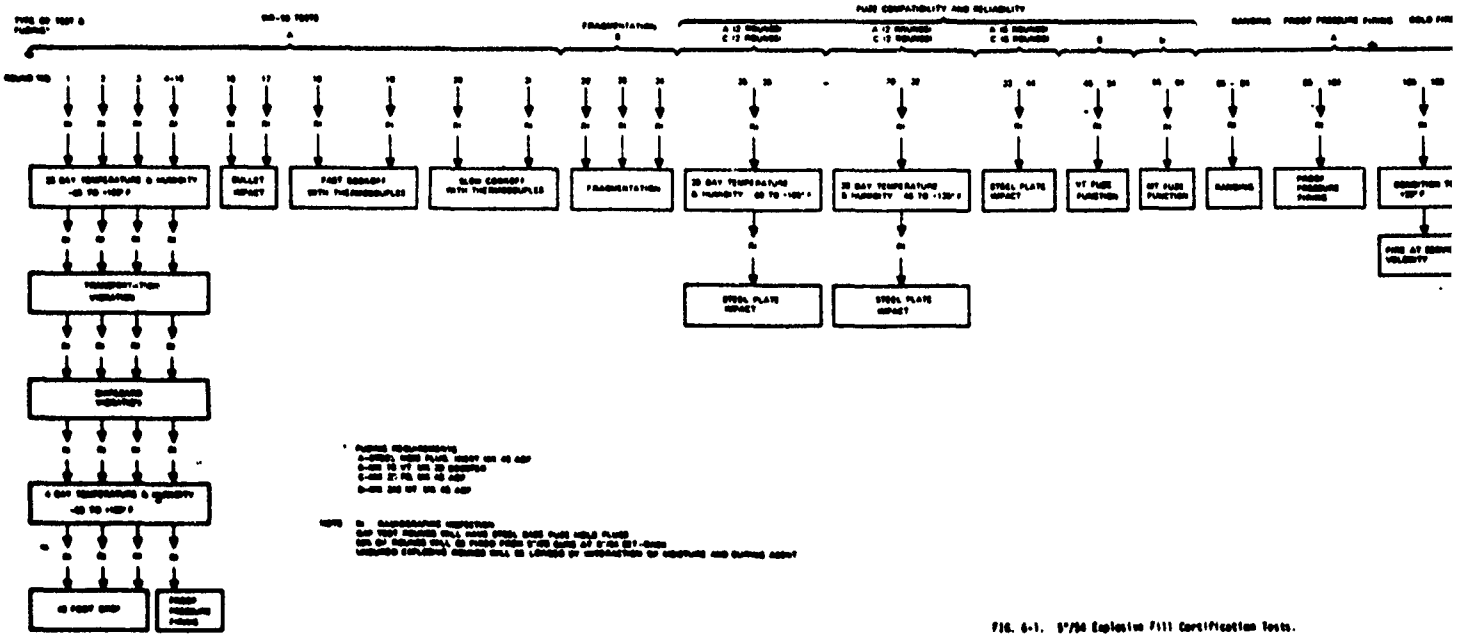

FIG. 6-1. 5"/54 Explosive Fill Certification Tests.

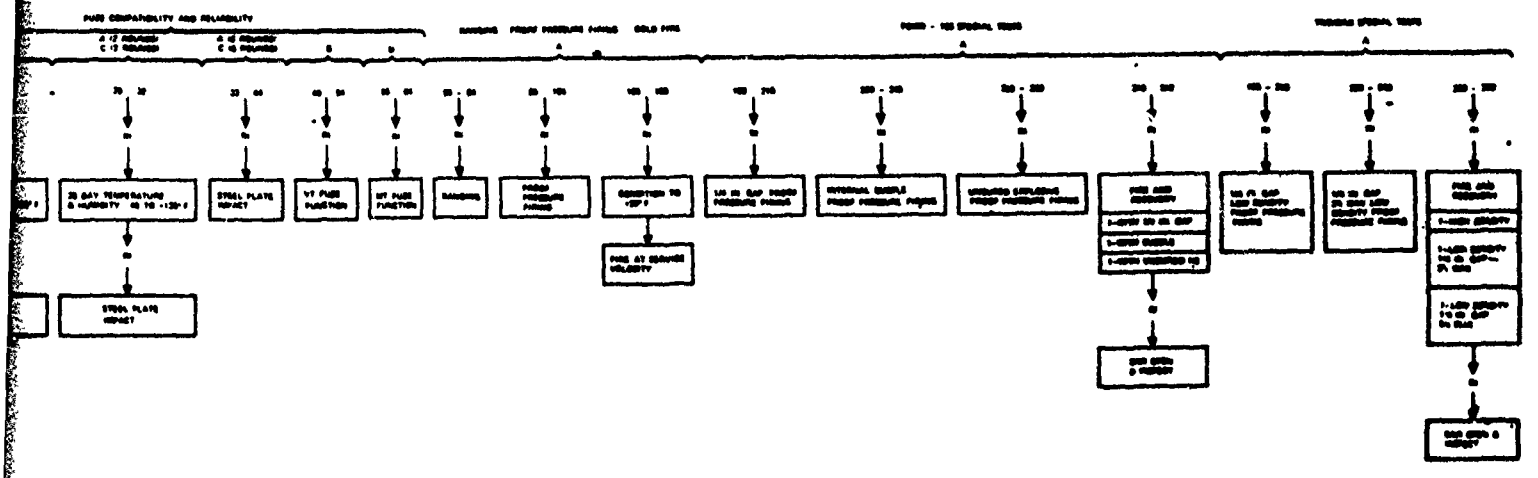

FIG. 6-1. 5"/54 Explosive Fill Certification Tests

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CONTENTS

1. EQUIPMENT

1.1 ABL-Modified Bureau of Mines electrostatic discharge machine.

1.2 5 KV power source.

1.3 Test plates.

1.4 Acetone or other solvent.

1.5 Non-sparking conductive spoon.

2. EXPLOSIVE LIMITS

2.1 The explosive limits will be as follows: Propellant and/or propellant ingredient (Class A or Class B) ..... 1 pound.

2.2 For extremely sensitive materials, such as raw nitroglycerin, a tote barricade must be used to store the material while it is in the laboratory. If materials are to be kept in a desiccator, a desiguard (metal cage) must be around the desiccator.

2.3 All propellants and propellant ingredients which have been tested must be removed from the laboratory at the end of the day and stored in a magazine. If a sample has not been tested or the test is not complete, the sample can remain in the laboratory overnight but must be kept in a tote barricade or in a desiccator with the desiguard around the desiccator. There will be no more than one sample in each tote barricade or desiccator and the quantity of sample will not exceed 20 grams. The laboratory door must be locked and a sign posted on the outside of the door stating whom to contact in case of an emergency. A placard will be placed on the outside of the door stating.

EXPLOSIVES
LABORATORY SAMPLES

2.4 The maximum amount of explosives per shot will be as follows:

Solid Propellants	50 mg.
Powders or Granules	50 mg.
Casting Powders	150 mg.
Liquids	25 mg.

3. PERSONNEL LIMITS

3.1 A maximum of five people can be in the laboratory when tests are conducted. For example one operator on impact test, one on ESD test and one on friction test plus two transients. A laboratory test can be performed by one man only if another man is on the same floor level in the immediate area.

4. PREPARATION BEFORE TESTING IN LABORATORY

4.1 Clean the ten metal plates with acetone and allow to dry.

4.2 If a solid material is tested, the operator must wear asbestos gloves and a face shield to cut the sample. The operator will use a scalpel and cut a sample about 0.03 inches thick and 3/16 inch square. The sample weight will not exceed 50 mg.

4.3 If powders are tested, the operator will spread the powder in a monolayer on the metal plates. The sample weight will not exceed 50 mg. For casting powders, the sample weight will not exceed 150 mg.

4.4 If liquids are tested, the operator will use a medicine dropper and place a couple of drops in the cup on the metal plate. The sample weight will not exceed 25 mg.

4.5 If solid flakes or powders are accidentally spilled, the operator will immediately clean up the material with a brush and dust pan and place the scrap in a conductive polyethylene bag. If liquids are accidentally spilled, the operator will immediately clean up the spill with acetone and kimwipes and place the scrap in a conductive polyethylene bag with sawdust. The polyethylene bag must contain sufficient sawdust to absorb the liquid waste. If nitroglycerin solvent is accidentally spilled, NG killer must be used after the contaminated area has been cleaned with acetone.

5. RELIABILITY OF TESTS

5.1 The first day of each week, a dried sample of nitrocellulose will be tested to establish the failure and shot level. The energy for the five consecutive failures will be performed at the zero initiation level and the energy for the five consecutive shots will be at the 6.25 joules level.

5.2 The capaciters should be checked on a monthly basis if the machine is used regularly.

6. TEST PROCEDURE

6.1 Operator "A" will record all pertinent information from the sample card into the laboratory book. If there is no sample card, the operator will notify the engineer in charge immediately and wait for instructions.

6.2 Operator "A" will open the door of the electrostatic machine and raise the discharge needle to its maximum height.

6.3 Operator "A" will plug in the power source, turn on the switch, and let the power source warm up for 2 minutes.

6.4 Operator "A" will adjust the voltage control to 5 kilovolts.

6.5 Operator "A" will place the metal plate with the mounted sample on the holder in the machine. The remaining working samples will be stored in an approved storage locker (metal cabinet).

6.6 Operator "A" will raise the capacitor switch or switches to "on" position for the desired energy level. (See Table A-1 for the standard test intervals.)

6.7 Operator "A" will close the door of the electrostatic machine and notify other personnel in the room that he is about to test. All other tests must stop until the electrostatic shot is complete.

6.8 Operator "A" will charge the capacitors by closing charge switch on the power source and hold in that position for 5 seconds or until dial on power source reads 5 KV again.

TABLE A-1. Standard Test Interval for Electrostatic Sensitivity.

Joules at 5000 volts	Microfarads
6.25	0.5
1.25	0.1
0.625	0.05
0.25	0.02
0.012	0.001
0.006	0.0005
0.001	0.0001

6.9 Operator "A" will release the charge switch, then lower discharge needle slowly until there is one arc from the needle to the test sample.

6.10 Operator "A" will raise the discharge needle and open the door of the electrostatic machine.

6.11 Operator "A" will record the results. A positive shot is any evidence of decomposition such as smoke, flame, flash, odor, or noise other than the sound of the machine.

6.12 Operator "A" will lower capacitor switches to "off" position and remove the test metal plate.

6.13 Operator "A" will raise or lower the energy level depending on whether the trial was a failure or a positive shot.

6.14 Operator "A" will wipe the needle after every shot with a kimwipe and change the needle after every five trials.

6.15 Repeat steps 6.2 through 6.14 until 20 consecutive failures at the highest possible energy level have been obtained.

7. TEST SEQUENCE FOR ELECTROSTATIC DISCHARGE

7.1 When starting a determination, begin at the maximum energy level (6.25 joules) and lower the energy level in the increments specified until 20 failures are obtained. Discontinue testing at a particular level at any time a shot occurs. In those cases where no shots are obtained at 6.25 joules initially, check sample at 0.625 and 0.012 joules since the 6.25 joule level may "blow" the sample away, preventing ignition.

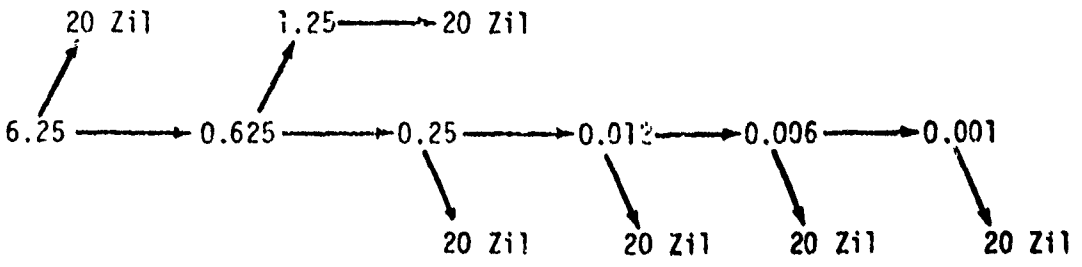
CASE 1 UNKNOWN SAMPLE

7.2 Start at 6.25 joules; if results are negative continue testing at 6.25 joules until 20 consecutive failures are recorded 20 Zil.

7.3 If test sample should give a positive result such as a flash, sparks, burn or odor, then the next test interval is 1.25 joules. See Table A-2 for test sequence.

NOTE. The procedure to follow is to halve intervals until there is still an untried value on either side of the proposed test. Operator will perform five tests per trial or until positive results occur.

TABLE A-2. Test Sequence for Electrostatic Machine.



CASE 2 KNOWN SAMPLE

7.4 Start at the next higher interval as determined in CASE 1 (for example if known result is 0.25 joules, start at 0.625 joules).

0.625 1.25 Work up (if negative)

0.25 Work down (if positive)

8. SPECIAL SAFETY PRECAUTIONS

8.1 Operators must wear safety glasses while in the laboratory.

8.2 Operators must wear asbestos gloves and face mask when slicing solid propellants or explosives.

8.3 The test sample for an electrostatic discharge trial will not exceed the explosive limits of paragraph 2.4.

8.4 If a sample is accidentally spilled, the cleanup procedure of paragraph 4.5 must be followed.

8.5 The operator must remove waste scrap from the laboratory at the end of the day's testing.

8.6 The operator must notify everyone in the room prior to a shot, and all other testing will stop until the electrostatic test is complete.

CONTENTS

PREAMBLE

This Appendix outlines the Adiabatic Sensitivity testing of explosive samples. The test is an outgrowth of work begun at the R&D Laboratory, NWS/Yktn during the early 1950's. Personnel using this document are invited to submit suggestions for improvement in the methods documented, and to report any errors found to the Commanding Officer, Naval Weapons Station, Yorktown, Va., 23491.

1. ADIABATIC SENSITIVITY TEST

1.1 Test Equipment.

Tests are performed on an Adiabatic Sensitivity Testing Machine described in Fig. B-1. Weights of 2.5 and 5.0 kg are available for impact on the air compressing piston. Samples are press-loaded in sample holders as described in paragraph 2.1.

1.2 Test Procedure.

A 50% sensitivity height (centimeters) is calculated on the basis of 25 shots at 0.05 log height intervals. The sample size is approximately 1 gram and is press-loaded into the sample holder. Positive stops are fixed to the loading tools to insure a constant explosive height of 0.375 ± 0.001 inches. Explosive weights are adjusted to give the required loading density. In general an explosive will be tested at the munition loading density. A detailed operation procedure, drop height sequence selection of gap sensitivity test heights, preparation of samples, and an example of sensitivity calculations are included in the following sections.

2. NcDED PROCEDURE FOR ADIABATIC SENSITIVITY TESTING

2.1 Sample Preparation.

2.1.1 Press Loaded Compositions (PBXN-1 Through PBXN-99).

2.1.1.1 Clean sample holder with trichloroethylene followed by an acetone rinse. Dry thoroughly.

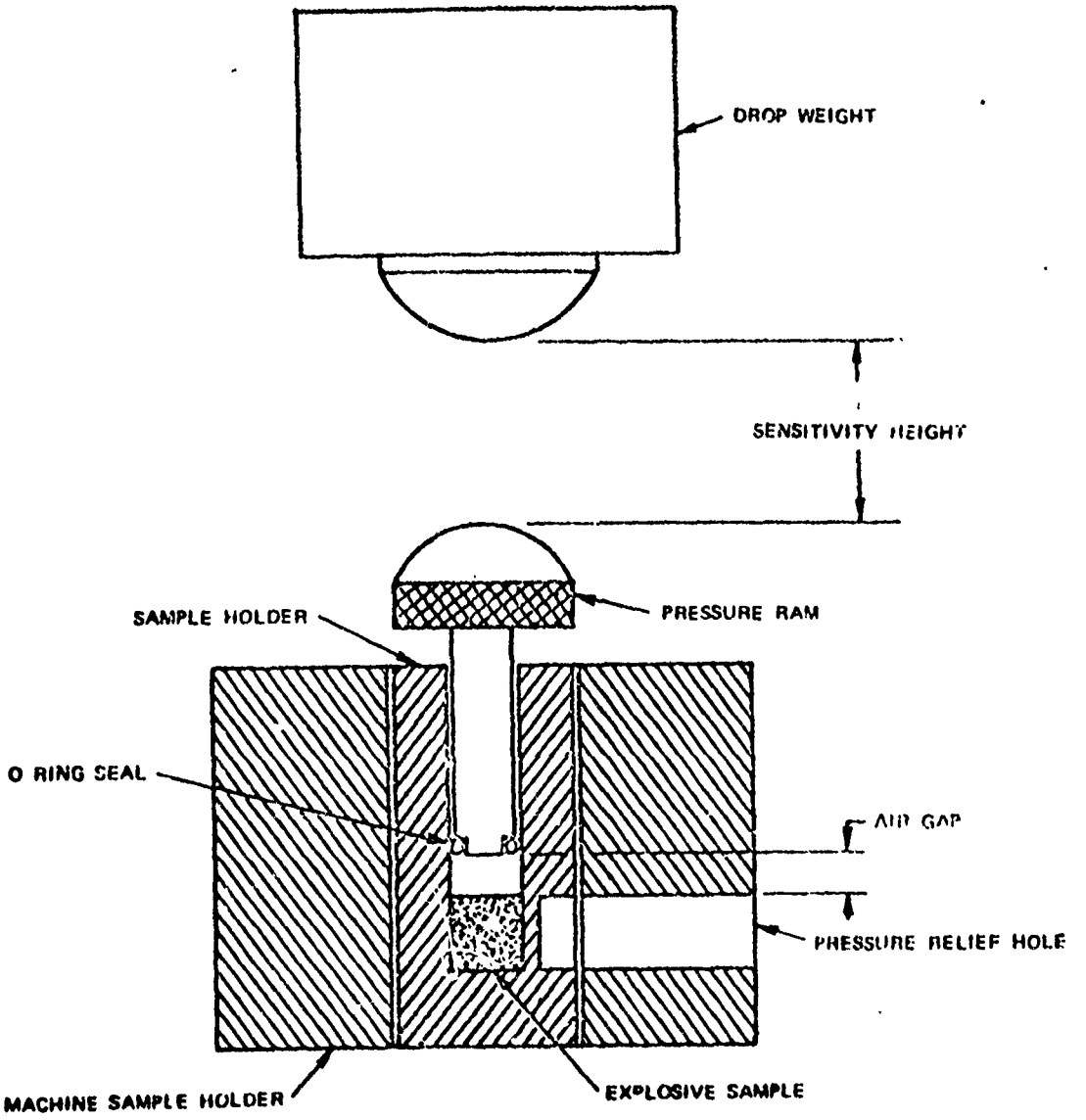


FIG. B-1. Adiabatic Sensitivity Test Machine.

2.1.1.2 Weigh the required sample on an analytical balance.

2.1.1.3 Pour sample in holder and compress to stop on loading ram.

2.1.1.4 Twenty-five samples are required for test. Extra samples may be required to establish a starting point.

2.1.2 Castable PBX Systems and Other Fluid or Semi-Fluid Systems.

2.1.2.1 Clean sample holder as specified in step 2.1.1.1.

2.1.2.2 Cast, extrude, press, or otherwise load a quantity of material in the sample holder to the required density.

2.1.2.3 Machine excess to a depth of 1 ± 0.001 inch using a reamer by appropriate explosive machining operation. Explosive sample height should be 0.375 ± 0.001 inch.

2.1.2.4 Twenty-five samples are required for test. Extra samples may be required to establish a starting point.

2.2 Machine Operation.

2.2.1 Select the weight specified on the data sheet and install in the machine.

2.2.2 Ensure safety stops are operable and in the loading position. (In position to prevent weight from impacting on sample holder.)

2.2.3 Engage vacuum plate and raise weight to starting position.

2.2.4 Install loaded sample holder with desired ram/explosive gap in machine - ensure pressure relief holes are in alignment and wood barricades are in good condition.

2.2.5 By remote control, withdraw safety stops and permit weight to impact on pressure ram.

2.2.6 Clear machine by raising weight and reinserting safety stops. Remove sample holder. Sample may or may not have been completely expended. Soak holder and piston in acetone to loosen piston and dissolve explosive residue.

2.2.7 Carefully remove piston from sample holder and clean.

2.2.8 Discard sample holder in explosive contaminated scrap.

2.2.9 Do not retest or reimpact any sample test holder.

2.2.10 Record results. A failure to fire is recorded N, a fire as E.

2.2.11 Repeat Steps 2.2.2 through 2.2.10 for each of the 25 samples.

2.2.12 Pistons should be changed when the surface is scored from the shot and must be cleaned between shots.

2.3 Selection of Gap.

The initial gap selected is largely dependent on the sensitivity of the material to be tested. With unknown materials, a minimum gap of 1/16 inch should be selected on first trial, up to the limit of the machine. If within the limit of the machine the samples fail to detonate, a larger gap may be selected. The gap should be selected in increments of 1/16 inch. This process or selection of gap should proceed until a drop height is established with the smallest gap that will permit the sample to detonate. When recording data, it is important to also record the gap used for any given trial.

3. RECORDING AND CALCULATION OF RESULTS

3.1 Data Sheet.

3.1.1 Record on data sheet (Fig. B-2 and B-3) information required at heading for each set of samples to be tested.

3.1.2 Record drop weights results on data sheet (E or N). Record multiple detonations or other abnormal conditions on back of data sheet indicating height level at which event occurred.

3.2 Calculation of Results.

3.2.1 Calculation of the 50% point (Fig. B-4) is done by either of the following methods:

Date_____Run No._____
Gap_____Density_____
Material_____
Remarks_____

Date_____Run No._____
Gap_____Density_____
Material_____
Remarks_____

Ht	EN	Ht	E/N

Ht	E	N	A	AE or AN

50% Ht_____

Ht	EN	Ht	E/N

Ht	E	N	A	AE or AN

50% Ht_____

FIG. B-2. Sample Data Sheet.

Date_____Room Temp_____Sample Temp_____

Explosive_____Gap_____in.

Ht	E/N	LO/HO*

Ht	E	N	A	AN

50% Ht_____cm

*A "low order" (LO) expels the piston back out of the sample holder, a "high order" (HO) ruptures the sample holder blowout disc and the piston remains in place.

FIG. B-3. 1st Revision to Data Sheet, Required for PBXW-106 Type Explosives.

Date: 21 Jun 1966 Run No.: 1

Scoop No.: 3 Particle Size: Thru 20-mesh U.S. Standard sieve

Material: (Type of explosive)

Remarks: Since $\Sigma E < \Sigma N$ use:

50% ht. = (Lowest normalized ht.)+(normalized intervals)$\left[\frac{\Sigma AE}{\Sigma E} - 0.05\right]$

Ht. level	E/N
20	E
19	N
20	N
21	E
20	E
19	N
20	N
21	N
22	E
21	E
20	E
19	E
18	N
19	E
18	N
19	N
20	E
19	N
20	N
21	E
20	N
21	N
22	N
23	E
22	E

Ht. level	E	N	A	AE or N
18	0	2	0	0
19	2	4	1	2
20	4	4	2	8
21	3	2	3	9
22	2	1	4	8
23	1	0	5	5
	12	13	-	32

$$\log 50\%\ \text{ht.} = 1.5551 + 0.05\left(\frac{32}{12} - 0.05\right)$$

$$= 1.5551 + 0.130$$

$$= 1.685$$

From Table B-1:

antilog 1.685 = 48.4 cm.

$\therefore$ 50% ht. is 48.4 cm.

FIG. B-4. Example of Data Sheet.

If ΣE is the smallest, use

$$50\%\ \text{pt.} = (\text{lowest normalized ht}) + (\text{normalizing intervals})\left[\frac{\Sigma AE}{\Sigma E} - \log \text{interval}\right]$$

If ΣN is smallest or if ΣE and ΣN are equal, use

$$50\%\ \text{pt.} = (\text{lowest normalized ht}) + (\text{normalizing interval})\left[\frac{\Sigma AN}{\Sigma N} + \log \text{interval}\right]$$

3.3.2 When reporting a 50% pt, the following information is also required.

a. Gap (space between ram surface and explosive surface)
b. Drop weight size
c. Loading method

The above equation is described in detail in Applied Mathematics Panel Report 101:1R, Statistical Analysis for a New Procedure in Sensitivity Experiments 1945-1948 and in general in the analytical method used in the Bruceton Impact sensitivity test. Normalized log heights are shown in Table B-1 for a common log interval of 0.05.

4. DEFINITION OF TERMS

4.1 Schematic of test - see Fig. B-1.

4.2 50% pt. = Adiabatic sensitivity of the sample lot under test conditions.

4.3 Lowest normalized ht. = log value of the lowest height used in the run of 25 shots.

4.4 Normalized interval = the difference between log hts.

4.5 A = level of the step height (the lowest step height in the series is designated as level zero; the next step height upward is considered Level 1; the next Level 2, etc.)

4.6 E = number of explosions at a given A level.

4.7 N = number of non-explosions at a given A level.

4.8 AE = A times E.

4.9 AN = A times N.

TABLE B-1. Impact Sensitivity Test Heights.

Level	Height, cm	Log height	Level	Height, cm	Log height
0	4	0.6051	19	40.5	1.6051
0.5	4.5	0.6551	20	45	1.6551
1	5	0.7051	21	50.5	1.7051
2	6	0.7551	22	57	1.7551
3	6.5	0.8051	23	64	1.8051
4	7	0.8551	24	71.5	1.8551
5	8	0.9051	25	80.5	1.9051
6	9	0.9551	26	90	1.9551
7	10	1.0051	27	101	2.0051
8	11.5	1.0551	28	113.5	2.0551
9	12.5	1.1051	29	127.5	2.1051
10	14.5	1.1551	30	143	2.1551
11	16	1.2051	31	160.5	2.2051
12	18	1.2551	32	180	2.2551
13	20	1.3051	33	202	2.3051
14	22.5	1.3551	34	226.5	2.3551
15	25.5	1.4051	35	254	2.4051
16	28.5	1.4551	36	285	2.4551
17	32	1.5051	37	320	2.5051
18	36	1.5551			

4.10 ΣAE = summation of AE values.

4.11 ΣAN = summation of AN values.

4.12 ΣE = total number of explosions.

4.13 ΣN = total number of non-explosions.

4.14 Air gap - the distance between firing punch face and explosive surface. See Fig. B-1.

4.15 Loading density - normally the explosive sample will be loaded by the same method and to the same density as expected in the service munition.

4.16 Non-impact punch - A punch so ground to length that machine stops preclude the punch from impacting on the sample. In the NEDED machine and sample holder design, the length is 1.000 inch from shoulder to face of punch.

4.17 Impacting punch - A punch of sufficient length to impact on the explosive sample. In the NEDED machine and sample holder design, the length is 1.250 inches.

5. ADIABATIC SENSITIVITY MACHINE, DROP HEIGHT SEQUENCE

Use the starting height and conditions designated on the data sheet, or select one in the range where the 50% pt is expected. Go up the height scale sequence until a detonation occurs; record this on the data sheet as the first shot. If a detonation occurs on the first shot, go down the height scale sequence until a non-explosion occurs. Example: When an explosion occurs, go down one step height, continue down in step increments until a non-explosion occurs, then proceed up in step increments until an explosion occurs. Repeat up and down through explosions and non-explosions until sample of 25 has been completed. Calculate 50% pt as specified in Section 3.

6. GENERAL COMMENTS

The number of variables in this test make it imperative that a standard procedure be established and followed for loading sample holders and conducting test runs. The test is designed to show worst conditions; a sample tested in this machine may be, in fact, less sensitive when tried in the actual munition but not the reverse. Finally, it is expected to show an ordered ranking of sensitivity to this stimulus. The ranking of explosives by this test must also be judged by other sensitivity tests.

CONTENTS

1. INTRODUCTION

An important problem faced by the designer of fragmentation warheads, is that he must maximize the energy which is transferred from explosive to metal during the detonation. The most frequently encountered configuration is that of an explosive-filled metal cylinder, detonated by a wave moving axially. The best scaling law that has been devised for this condition is that of Gurney, Ref. 1, who disregarded detonation conditions, shock effects in the metal, and assumed implicitly that all the energy of the explosive is conserved. His equation for cylinders is:

$$v = \sqrt{2E}\left\{\frac{C/M}{1 + 0.5\ C/M}\right\}^{1/2}$$

where v is the velocity to which the metal is accelerated by the explosive, E is unit energy content of the explosive, C is the weight of the explosive and M is the metal weight. This expression of velocity in terms of C/M implies that weight-ratio scaling of explosive and metal is of prime importance and that dimensional scaling need not be considered at all. The term $\sqrt{2E}$ has the dimensions of a velocity as was pointed out by Gurney in his original report.

Determination of the Gurney constant of a warhead explosive is logically made in the cylinder expansion test where the explosive contained in a metal cylinder is end-detonated and the maximum lateral velocity of the metal is measured. The geometry resembles that of most fragmentation warheads, particularly as to lateral confinement of the explosive. The dimensions of the cylinder can be chosen so as to give the full run-up to detonation velocity before reaching the location of fragment velocity measurements, and the end-release effects can be kept far enough downstream so as not to affect fragment velocities. Other techniques for evaluating explosives, while of full value in their own contexts, are all less applicable to the prediction of effects in the fragmentation warhead. The plate-push test transfers only about one-fourth as much of the energy of the explosive to the metal as does the

cylinder expansion; also, the air-cushion between explosive and plate is highly unrepresentative of the warhead configuration. Other rating tests such as the plate-dent, and ballistic mortar and the Trauzl lead block are even more unrepresentative, geometrically.

The cylinder expansion test has been in use for some time. Early work at the Naval Ordnance Laboratory (NOL), White Oak successfully used the streak camera to record metal velocities; techniques developed by the Lawrence Radiation Laboratory (LRL) and the Los Alamos Scientific Laboratory (LASL) in this country and the Atomic Weapons Research Establishment (AWRE) in Britain have given results of good precision and in agreement among the three organizations. This latter test geometry was chosen for the work at NWC.

2. BACKGROUND

The cylinder expansion test is any test performed where a metal cylinder (relatively thin walled), is loaded with an explosive and this explosive charge detonated. As the detonation occurs, the expansion of the cylinder wall is observed and recorded in such a way that the rate at which the wall moves outward can be followed up to the point where the expanding cylinder wall is obscured by the reaction products as they break through the wall.

The method for observing the wall's expansion varies. It has been recorded through the use of electronic pin probes and raster oscilloscope recording systems as well as with flash X-ray techniques. It has also been accomplished by the use of streak cameras and framing cameras. The Lawrence Radiation Laboratory (Ref. 2) method uses a streak camera for the recording of the wall velocity and a pin probe method for determining the detonation velocity of the explosive while it is expanding the walls of the test cylinder. The AWRE uses both electronic pin probe and streak camera methods (Ref. 3) to record the wall expansion, and pin probes for the detonation velocity. There is some reason to believe that perhaps in the early stages of the expansion the pin probe method

may be more accurate, but the data reduction is also a bit more difficult in some respects than with the streak camera record.

A standard cylinder geometry is selected and manufactured precisely from a standard metal. The cylinder thus produced, is loaded with a carefully manufactured explosive charge of the material to be investigated.

The test assembly is then instrumented in any of those methods mentioned above and fired, recording the detonation velocity of the charge, and also the radial expansion of the cylindrical case, as a function of time. Reduction of these data permits an assessment of the explosive's behavior during the event.

When various explosives are rated in the standard geometry, the relative performance of these explosives becomes readily apparent. This permits the warhead design engineer to select an explosive compound for a specific feature of its performance.

It has been demonstrated that cylinder expansion test results scale up or down over a wide range of sizes (Ref. 2).

3. NWC CYLINDER EXPANSION (CYLEX) TEST

3.1 Experimental Considerations.

The test device consists of a 2.54-cm ID, precision manufactured copper cylinder, 12 diameters long and with a wall thickness of 0.25 cm.

Copper was chosen because in cylindrical geometry it is capable of nearly twice the expansion steel demonstrates before the wall ruptures, thus containing the explosive gases until terminal wall velocity is reached. Figure C-1 shows the Cylex test assembly positioned as viewed by the streak camera. The black and white placard behind the cylinder is a focusing aid to determine an accurate magnification factor for use in data reduction. At present, detonation velocity of the explosive is measured using electronic switches. In Fig. C-2, the two end supports of the cylinder can be seen to incorporate detonation velocity switches.

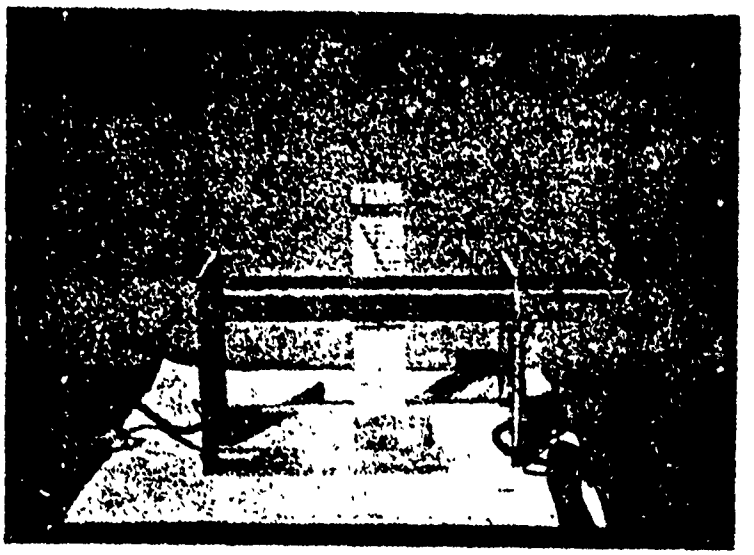


FIG. C-1. Cylex Test Assembly, Positioned as Viewed by Streak Camera.

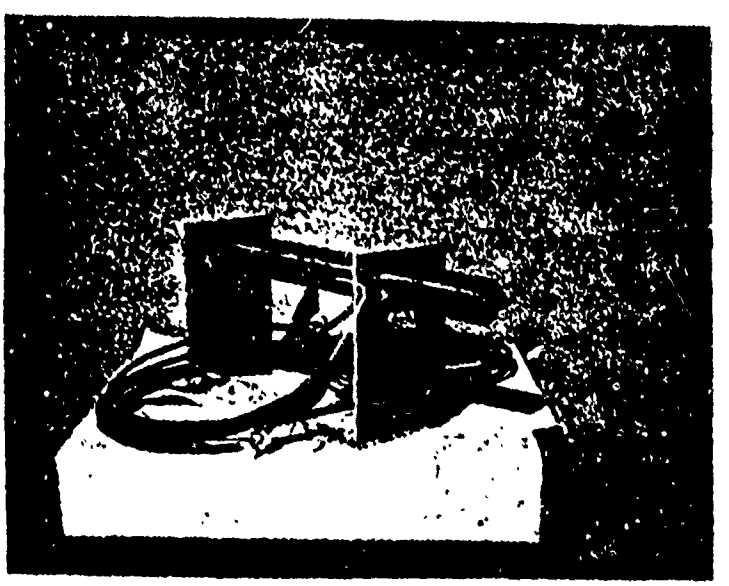


FIG. C-2. Cylex Test Assembly Showing Detonation Velocity Switches.

Two circuits (each using a nanosecond counter) are employed on each experiment. This permits a more confident determination of the detonation wave's transit time through the measured interval--the time interval is relatively long (25 μ-sec) and the distance traversed is about 21.5 cm. The counters record the signals generated from printed circuit boards, which are placed on the cylinder's wall, in an area which does not affect the wall and its expansion behavior, but which does record the detonation velocity of the explosive accurately.

The castable plastic bonded explosive used as the standard of comparison in the Cylex test is PBXN-101 rather than Composition B because it is a more homogeneous composition, and is structurally a considerably better explosive. Further, in making this choice, the undesirable variability of the melt-cast TNT explosive systems is avoided.

The instrumentation for this test consists of a streak camera to monitor the expanding cylinder wall and electronic means to record the detonation velocity of the explosive as it is expanding the test cylinder wall. The camera is a Cordin 70 mm streak camera, which records its image on a large strip of film. Optical magnification is selected for each explosive in order to provide maximum accuracy and precision in recording the data from the firings. The writing speed of the camera (again selected for each explosive compound to maximize the sensitivity of the data recording) is recorded with a period lockout count circuit, (Ref. 4) so as to obtain as precisely as possible, the exact writing speed of the camera during the revolution of the mirror on which the experiment was fired.

The printed circuit board pin probe arrays are capable of being semi-mass produced to close tolerances. In addition, they are compatible with automated-record-reading machine calibration procedures.

The test cylinder is placed at an appropriate distance in front of a tracing paper screen which is illuminated by an argon-filled explosive flash lamp. This system provides the proper contrast for good photographic rendition of the dynamic event (Fig. C-3).

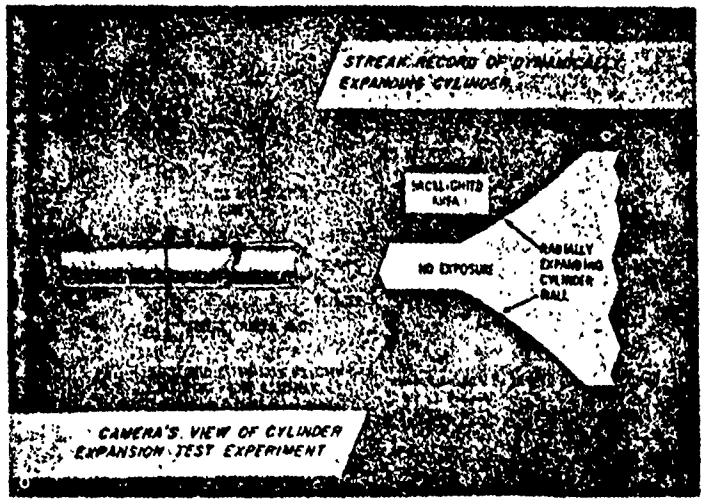


FIG. C-3. Streak Record of Dynamically Expanding Cylinder.

An optical alignment is accomplished through the use of a Laser. The cylinder assembly is so positioned that the projected slit image of the camera which records the radial velocities, one on the upper side of the picture and one on the lower side of the picture, will cross the cylinder at a point at least 6 charge diameters from the initiation end. It has been found (Ref. 5) that in a series of experiments, where the projected camera slit images were placed at different locations along the cylinder, it was not until 6 diameters from the initiated end of the cylinder that the wall velocity reached a steady state value. Recorded wall velocities remained constant until 1.5 diameters from the free end of the cylinder. After this distance, the wall velocity values again varied downward from the constant, maximum values.

3.2 Data Reduction.

Data reduction for Cylex testing is an automated procedure (see Section 3.4). It consists of a Mann Comparator using IBM card printout to actually read the data from the film. A computer program written on the IBM 1130 computer smoothes the radius and time data, fits the data,

and then the IBM 1627 Plotter plots it in various ways. One of the interesting plots is the smooth radius data versus time ($(R-R_0)$ verus T) (Fig. C-4). Figure C-5 displays the velocity obtained from the data plotted in Fig. C-4 as a function of time also. These two plots can be handled either geometrically or analytically to provide a velocity at a radius. This is the first bit of information specifically wanted.

The final data of interest from the Cylex test is the Alpha or Gurney constant. This is a factor used to calculate initial fragment velocity from an explosive (Ref. 1). Figure C-6 is a plot of the Gurney constant as a function of time. However, this plot is somewhat fictitious since there is only one Gurney constant for any given geometry, and the constant does not evolve. However, it proves to be easier to allow the computer to calculate something that is called Alpha and disregard the data until the 19-millimeter expansion point is reached. Therefore, the Gurney values that are given relate to information obtained from Fig. C-4, C-5, and C-6.

Figure C-7 shows a typical streak camera Cylex record for PBXN-5 explosive. There are several items in the record that are worth noting. The initial phase of wall motion shows an irregularity thought to be an initial jump-off of cylinder surface. This behavior was recorded by AWRE (Ref. 3), and by H. Dean Mallory (Ref. 6). It occurs early enough in the record and disappears soon enough so that it is not detrimental. It is interesting to note that while there is a clearly visible air shock moving ahead of the cylinder wall in the later stages of expansion, it does not affect the recording of cylinder wall behavior.

Velocity of the cylinder wall measured at two radii of expansion are of interest. These are 5 mm (wall expanded to 5 mm beyond original radius), and 19 mm of expansion. The velocity at 5 mm is said to be comparable to the Naval Ordnance Laboratory (NOL), White Oak, plate push velocity. This is defined as equivalent to the velocity of the cylinder wall after a two-fold volume expansion of the detonation products has occurred. The 19 mm point equates to a sevenfold volume increase of detonation products, and is quoted as the terminal velocity, or maximum velocity, that the subject explosive will contribute to the cylinder wall.

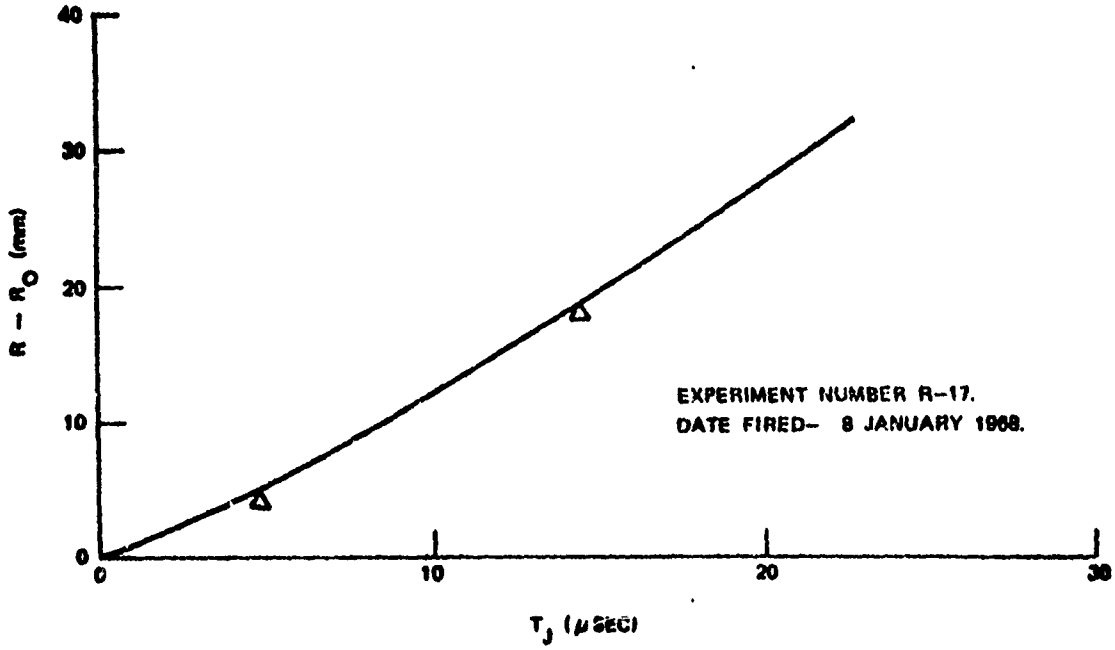


FIG. C-4. Expanding Radius Data, Plotted as a Function of Time.

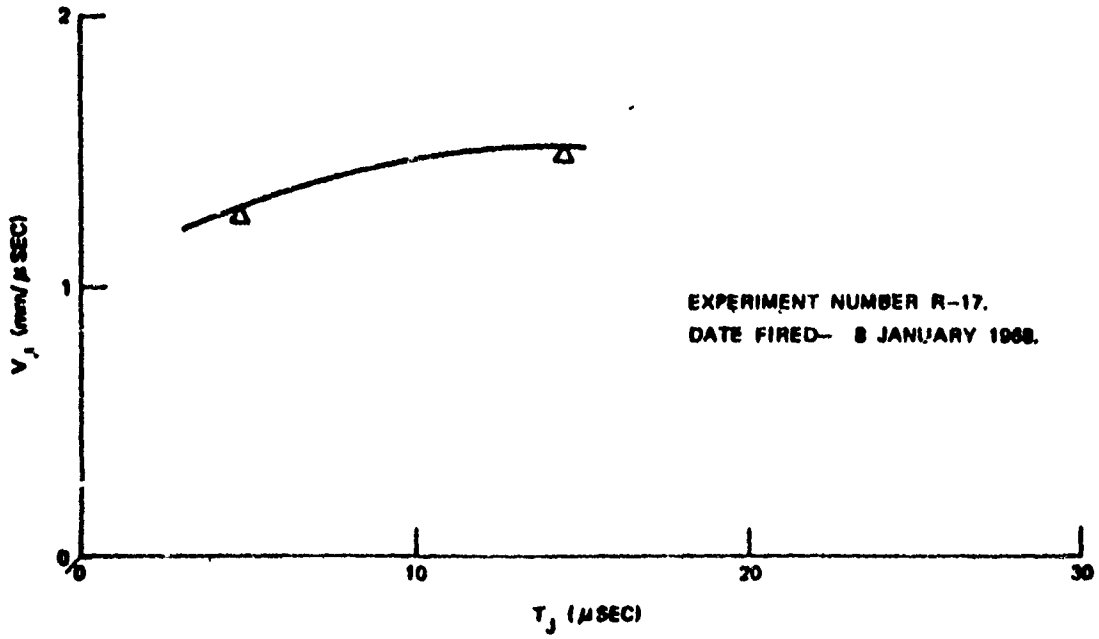


FIG. C-5. Cylinder Wall Velocity, Plotted as a Function of Time.

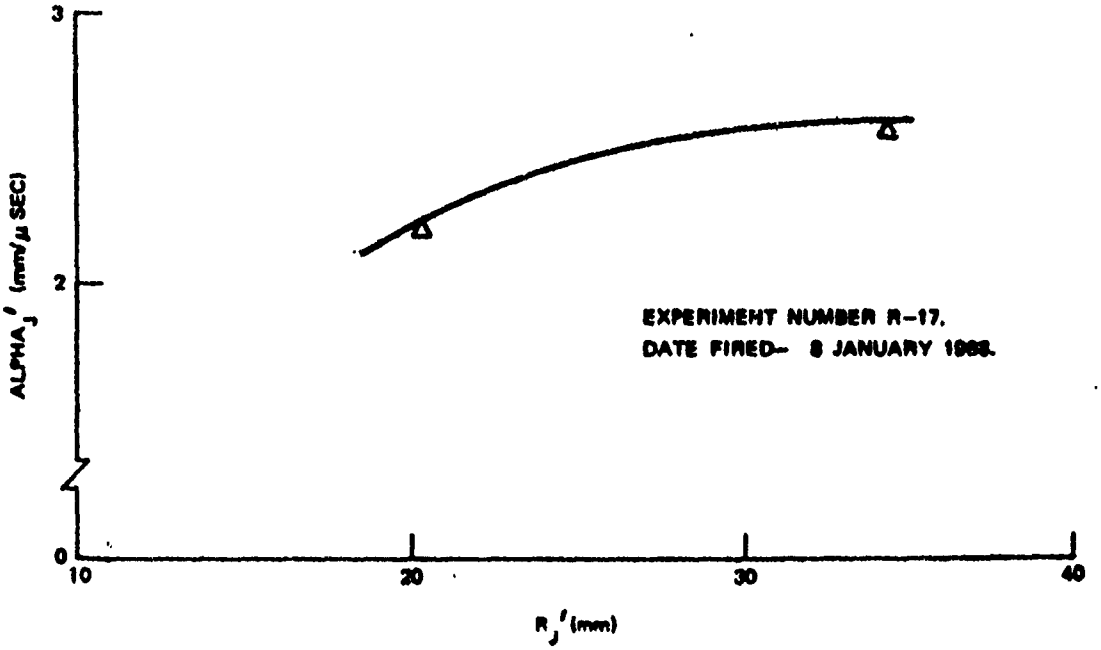


FIG. C-6. Gurney Constant Plotted as a Function of Time.

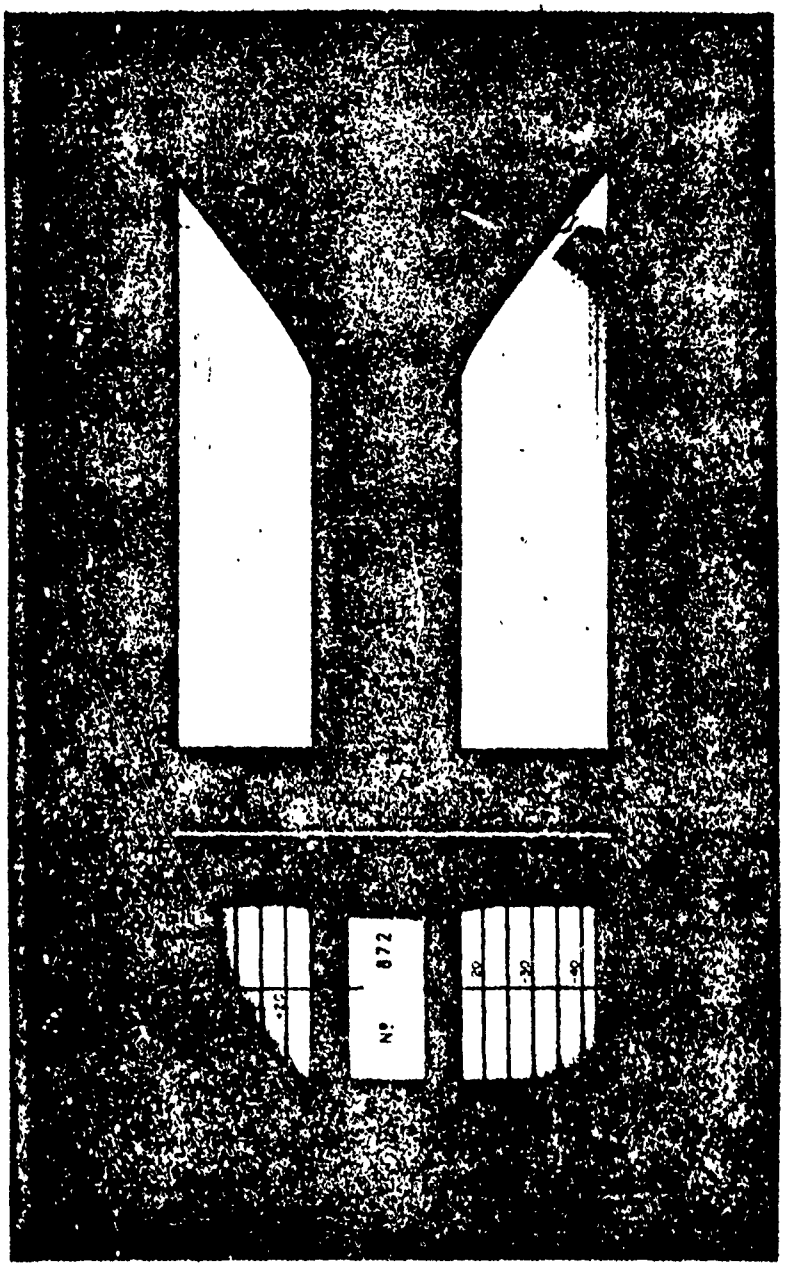


FIG. C-7. Streak Camera Record of PBXN-5 Explosive in the Cylex Test.

3.3 Sources of Error in the Cylex Test.

3.3.1 Error in Recorded Radial Wall Velocity Due to Camera Slit Tilt. If the camera's slit should be tilted away from normal or if the charge should be placed in an orientation other than parallel to the camera's time axis, erroneous velocities will be recorded. However, in monitoring the wall's expansion from both sides of the cylinder, a simple averaging procedure will remove all errors introduced in this manner.

3.3.2 Error in Wall Velocities Introduced by Faulty Determination of Optical Magnification Factor. By using a Laser to align the elements of the experiment before the camera, nearly optimum photographic conditions are obtained. This factor plus two others, (1) the standardization on one test geometry, and (2) working at an optical magnification of or near unity, results in high quality photographic records which make precision record reading possible.

3.3.3 Error in Measuring Detonation Velocity of the Explosive. The velocity of the detonation which is responsible for expanding the cylinder wall is on the order of four to five times higher than the velocity with which the expanding wall is moving. Because of this fact, then, in the time it takes for a point on the wall to move outward 1 millimeter after the detonation front has passed, the detonation wave will have run down the cylinder, 4 millimeters or more. For this reason, great care must be taken to insure that the pin contacts are all placed at both the exact same distance from the cylinder wall and as close as possible to the wall.

In the work at NWC, two factors have combined to produce precision results in detonation velocity measurement. The first of these is the production of flat calibrated pin probe arrays through the use of substantial, dimensionally stable printed circuit board materials. Second is the assurance that the plane of the contacts on this board is perpendicular to the cylinder axis.

3.3.4 Record Reading Errors. While a detailed assessment of the errors accompanying the record reading itself has not been made, during the course of the analysis for the first series of experiments described in Section V of this paper, it became possible to reread and recompute wall velocities for one record three times. These times were spread over a 6 months period, and involved two record reader operators (neither of whom knew which record they were reading). All three analyses yielded the same value with a total spread of 0.08%.

The data for the explosives studied using the Cylex procedure are omitted from this unclassified document. As additional data are obtained, a classified table will be updated and be available upon request.

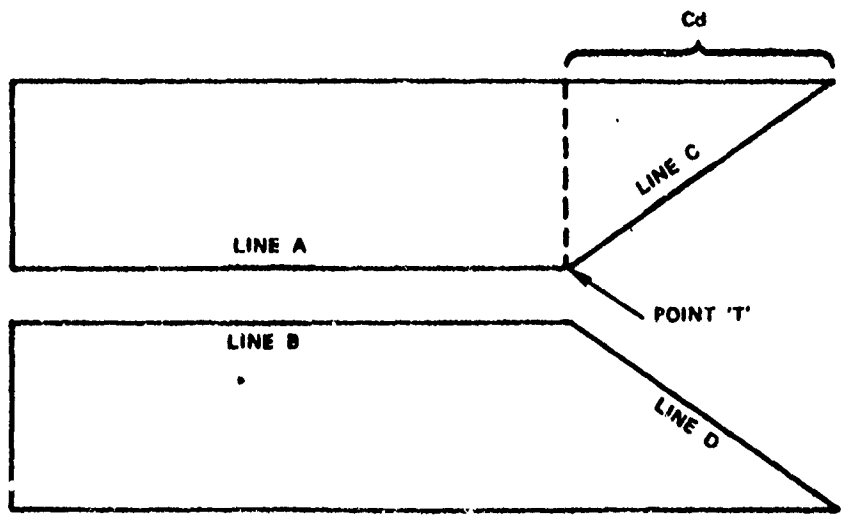
Future plans call for the inclusion of C-J pressure for these materials as well as the data already provided.

3.4 Cylex Data Reduction Procedure.

The following procedure is used for reduction of data from film strip records:

3.4.1 The film strip is read on the Mann Comparator in conjunction with a Telecordex unit and an IBM Summary Card Punch.

3.4.2 When the film has been placed on the Mann Comparator the following steps are followed:



3.4.2.1 The film is first aligned in the comparator such that moving along line A from one end of the line to the other will produce a deviation in Y counts (vertical measurement) of no more than ±5 machine counts.

3.4.2.2 When film has been properly aligned, an origin point is then determined. This origin point is normally a point at the extreme left end of line B. When the origin point has been determined, the X and Y digitizers are set to 0.

3.4.2.3 The next step is to find the diameter of the Cylex tube in machine counts. In order to obtain this distance, six readings are made of the vertical distance between lines A and B. The measurements would be punched on cards in the following manner:

Reading 1	X=0 counts	Y=30000 counts
Reading 2	X=5000 counts	Y=30005 counts
Reading 3	X=10000 counts	Y=30000 counts
Reading 4	X=15000 counts	Y=30001 counts
Reading 5	X=20000 counts	Y=29998 counts
Reading 6	X=25000 counts	Y=30003 counts

Past experience has shown that taking these measurements at increments of 5 mm in the X (horizontal) direction of movement produces a better average of the vertical distance between lines A and B than taking the measurements at shorter or longer intervals of X.

3.4.2.4 The next step is to obtain readings for trace line C. A minimum of 100 readings are needed for this line. In order to determine how often this line should be read the following procedure is used:

3.4.2.4.1 The film is advanced to point 'T' on the film and is then raised vertically to the top of the trace pattern and the distance in X counts is recorded. The film is then advanced to the end of the trace pattern and that distance in X counts is recorded. The first distance reading is then subtracted from the second distance reading and this value is distance Cd. Distance Cd is then divided by 100 to obtain the number of machine counts needed in order to obtain 100 readings of trace lines C and D.

3.4.2.4.2 To begin reading trace line C the film is advanced to point 'T' and the following procedure is used:

Assume that the X counts at point 'T' equal 27000 machine counts. It is desired to make one reading on line A before the trace line C is read. Assume also that it has been determined that trace line C is to be read every 300 machine counts in the X direction of movement. From point 'T' the film is advanced 300 counts in X to the left of point 'T' on line A. When this point has been reached the Y digitizer is set to 0 machine counts. Therefore the first reading for trace line C is equal to 26700 counts in X, and 0 counts in Y. From this point a reading is made adding 300 machine counts in X for each reading on trace line C. As each reading is made on trace line C the Y value will increase positively in machine counts as it follows the trace line.

Example: Trace line C readings

Reading 1	X=26700 counts	Y=00000 counts
Reading 2	X=27000 counts	Y=00001 counts
Reading 3	X=27300 counts	Y=00285 counts
Reading 4	X=27600 counts	Y=00570 counts

Notice that on trace line C both the X and Y counts increase positively.

3.4.2.5 When trace line C has been completely read the film is returned to point 'T' and then lowered vertically until line B is reached. For comparison purposes, the readings of the top and bottom trace should begin at the same point in the X direction of movement and readings of trace line D should be made at the same interval of X as was used for trace line C.

Example. Trace line D readings

Reading 1	X=26700 counts	Y=00000 counts
Reading 2	X=27000 counts	Y=-00001 counts
Reading 3	X=27300 counts	Y=-00286 counts
Reading 4	X=27600 counts	Y=-00573 counts

Notice that on trace line D the X counts increase positively in value while the Y counts decrease in value as it follows the trace line.

3.4.2.6 When trace line D has been completely read, the reading portion of the job is completed.

3.4.3 The next step in the reduction of the test data is to 80 x 80 list the deck of cards obtained from the film readings. The listing is then checked to verify that all appropriate readings have been made and that all cards are in their proper order.

3.4.4 The next step is to keypunch control cards containing the information given on the Cylex Calculation Input Sheet. A list of control cards is shown in Table C-1.

3.4.5 When the control cards have been punched and inserted at the beginning of the data deck, the deck is submitted to the IBM 1130 Cylex computer program. Data are output in the form of a data listing and 10 plots for each Cylex record, 5 plots for the upper trace readings and 5 plots for the lower trace readings.

3.4.6 The next step is to check the listing and each of the plots to determine if all the information required has been obtained.

3.4.7 When the Cylex data computer printout and plotout forms are received, make a work sheet as follows:

The work sheet will be made from a large piece of data paper. This has 22 columns from left to right, laid off by pink lines and 38 lines from top to bottom, laid off with blue lines. The work sheet is divided so that the first column is for experiment; second, half; third, leave blank; fourth, time at 5 millimeters; fifth, average; sixth, velocity at 5 millimeters; seventh, average; eighth, leave blank; ninth, time at 19 millimeters; tenth, average; eleventh, velocity at 19 millimeters; twelfth, average. The last columns are empty, however, they are useful for additional notes and corrections, etc. At the top of the page, designate the explosive being tested.

TABLE C-1. NWC Code 4541 Cylex - Control Cards for Program MAT 1.

Card #1	
Shot #:	Columns 1-5
Date Fired:	Columns 11-26
Operator:	Columns 31-51
Card #2	
80 Column ID Card.	
Card #3	
80 Column Comment Card.	
Card #4	
80 Column Comment Card.	
Card #5	
Type of Metal:	Columns 1-12
sm:	Columns 16-25
Type of Explosive:	Columns 31-42
sc:	Columns 46-55
Card #6	
Writing Rate:	Columns 1-10
Inside Radius:	Columns 11-20
Outside Radius:	Columns 21-30
Detonation Velocity:	Columns 31-40
Data Card	
Al Punch (constant):	Column 7
Reading #:	Columns 25-27
Machine #:	Column 37
Shot #:	Columns 47 & 48
Readout #:	Column 50
X counts:	Columns 62-66
Y counts:	Columns 67-72

3.4.8 Data Reduction.

3.4.8.1 $(R_J - R_0)$ Versus T_J Plot.

3.4.8.1.1 Take the $(R_J - R_0)$ versus T_J plot and lay it out on the table or a light box.

3.4.8.1.2 On the ordinate, mark off the 5 millimeter and 19 millimeter points.

3.4.8.1.3 Using the triangle, draw lines over to the plotted curve. These lines will be parallel to the abscissa.

3.4.8.1 4 At the point where they intersect the curve, draw a line perpendicular to the abscissa, thus marking the time at which the wall reached the radii of 5 millimeters and 19 millimeters respectively.

3.4.8.1.5 Record these values in the appropriate columns on the work sheet.

3.4.8.2 V_J Versus T_J Plot.

3.4.8.2.1 Take the V_J prime versus T_J plot and lay it over the R_J minus R_0 versus T_J plot, so that the time axes coincide, and fasten in place.

3.4.8.2.2 Take the triangle again and draw perpendicular lines from the time readings upward until they intersect the velocity plot at both 5 millimeter and 19 millimeter points.

3.4.8.2.3 At these two points, run lines that are parallel to the abscissa over to the ordinate, thus giving the velocity at these two expansion points respectively.

3.4.8.2.4 Record these values on the appropriate column on the work sheet. This reduction procedure is repeated for each half of each experiment (the corresponding entries being made on the line marked either 21 bottom or 21 top for instance).

3.4.8.3 After calculating the radial wall velocity for each experiment at each point, (the 5 millimeter point and the 19 millimeter point) the Gurney value is determined.

The procedure followed is to determine what appears to be the radial wall velocity, averaging all the radial wall velocity determinations for a set of experiments at 19 millimeters, then use this number to determine the Gurney value.

The easiest method is to use information from the particular plot of Alpha J', which corresponds to the average velocity or most nearly corresponds to the average wall velocity. At present, the Alpha J' plots Alpha J' against radius, but it's not $R - R_0$.

3.4.8.4 Alpha J' Versus R Plot.

3.4.8.4.1 Find the initial outside radius, add 19 millimeters to it, and go along the abscissa until you find this radius.

3.4.8.4.2 Construct a perpendicular line from this point upward until it intersects the curve.

3.4.8.4.3 Finally, construct a perpendicular line from this line to the ordinate which will yield Alpha. Alpha is given in millimeters per microsecond.

3.4.9 Helpful Hints.

3.4.9.1 A rubber ruler is very useful in reducing the data. Velocity, (V_J), time (T_J), Gurney constant (Alpha J'), and radius (R) use the same graduations requiring one setting of the variable scale.

3.4.9.2 The remainder of the data is on the printout heading for the experiment.

3.4.9.2.1 Charge/mass ratio (C/M) appears on the fifth line of the heading for each experiment.

3.4.9.2.2 Detonation velocity appears on the fifth line also. In some cases, the detonation velocity will be an estimate or will be given from other work, (not measured in the individual Cylex experiment). If the detonation velocity is not measured, there will generally be a flag in the title section of the computations that indicates this.

3.4.9.2.3 The sixth line carries metal identification and density. (Density is called out as RHOM.)

3.4.9.2.4 The explosive designation and explosive density are also on line 6. (Explosive density is called out as RHOC.)

3.4.9.3 If you label the work sheet with the types of explosive being tested, initial and date it, and make a brief statement as to where the data are reported; this makes reduction of the data easier the next time.

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CONTENTS

1. FACILITIES

As a result of the requirement to evaluate fuel-air explosives, a blast test facility has been developed at NWC. Measurement of blast parameters from fuel-air explosives (FAE) places some rather stringent requirements on facilities and instrumentation. In order to obtain quantitative data for evaluating the performance or blast output of an FAE device, measurements must be made in a rather difficult environment. The equipment must operate in an environment where peak reflected pressures can be in excess of 1,000 psi and intense heat pulses are generated.

Based on experience with FAE and drawing on the requirements for blast testing in general, several requirements of a blast test facility can be defined.

1. Uniform surface conditions for repeatability.
2. Rigid mounts for transducers.
3. No obstructions to perturb the blast wave.
4. A clean area for photographic coverage.
5. Flexibility to meet varying test requirements.

The blast test facility that has evolved at NWC is located at CT-6 and is operated by Code 4531.

One of the newer additions to the blast test facility is a concrete test pad. This pad is 148 feet long by 96 feet wide with one end being semi-circular with a radius of 48 feet. Located at the center of the circle that would be generated if the arc were continued is a 4 foot diameter hole or pit. This is where FAE devices are normally fired and the pit is used to catch the end-plate from the warheads.

Starting 3 feet from the edge of this pit are the combination instrumentation troughs and gage mounts. There are six of these gage lines extending radially from the firing pit (Fig. D-1). Each gage line consists of a trough in the concrete pad approximately 4 inches square in cross section. The cover is 3/4-inch-thick aluminum plates mounted flush

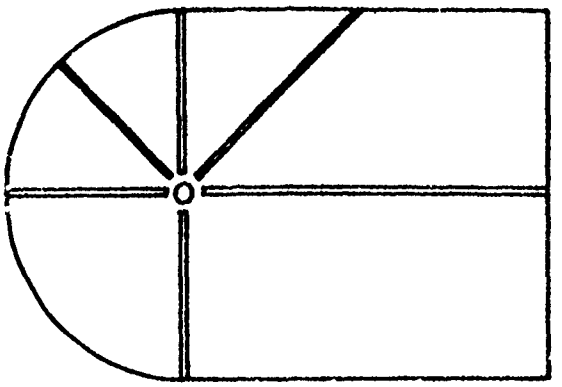

FIG. D-1. Pad Layout.

with the surface of the pad. These plates are firmly clamped at the edges and each plate is not longer than 6 feet for ease of handling. The blast pressure gages or other instrumentation are mounted directly in these plates.

Around the edge of the pad are junction boxes and conduit for instrumentation lines. These all feed into a common point and then back to the instrumentation and control bunker approximately 500 feet away.

On either side of the test pad and offset 15 feet from the firing pit are two 170 foot poles. These poles are designed to support loads up to 1,000 pounds, 150 feet above the pad. They are most frequently used to support a camera for overhead photographic coverage of test events, but may also be used for supporting or dropping weapons or other test items.

The instrumentation and control bunker is located behind an earth barricade approximately 500 feet from the pad. The instruments are housed in an old gun ship turret. This turret has been set into the earthen barricade for added shielding. A motor-generator unit regulates the electrical power and the instrumentation room is air conditioned, giving a favorable operating environment for the instruments in the bunker.

The instrumentation used to control the tests consists mainly of a timer-control unit that automatically turns circuits on and off at preset intervals relative to the firing signal. This is used to control the cameras as well as control test sequences. The timer-control unit has the capability of controlling 12 independent channels.

The instrumentation for gathering test data other than photographic data is centered around an Ampex FR1400 magnetic tape recorder. This is a 14 track recorder with a frequency response of DC to better than 400 KHz in the FM mode. Piezoelectic pressure transducers are typically used to measure blast overpressures. Low noise coaxial cables connect the transducers to the charge amplifiers located in the instrumentation bunker. Because of transducer limitations, the output of the charge amplifier is usually passed through a low pass filter with a roll off at 100 KHz. The charge amplifiers now in use, Dynamics Model 7350 modified for high frequency response, have been demonstrated to have a flat frequency response from 2 Hz to well in excess of 100 KHz, within ±2 db, when driving 500 feet of low noise coaxial cable.

The weakest link in the data gathering system is in retrieving the information from the magnetic tape. The signal is usually played back into an oscilloscope and the resulting trace photographed. Such parameters as peak pressure or positive phase duration may be read directly from the trace or, for more complete analysis, the trace may be digitized and the information fed into a computer for processing.

The primary pressure transducer used is the Susquehanna Model ST-2. It uses a lead metaniobate crystal as the sensing element and the first resonance occurs at 250 KHz. A nylon pressure plate protects the diaphragm, but additonal shielding in the form of a layer of pressure sensitive tape is also used. This tape may be black plastic electricians tape or other more sophisticated tapes such as fiberglass or Teflon. All have been used with approximately equal success. The main function of this tape is not to protect the gage physically but to delay the thermal pulse from reaching the sensitive element. This allows the pressure signal to be recorded

before the thermal pulse causes the output to drift. There are quartz transducers available that are essentially insensitive to thermal pulses, but the technique used above has given entirely satisfactory results at a significant cost savings.

The ST-2 transducers are normally flush-mounted in the gage line cover plates. However, they are not mounted directly in the plate but rather in a Teflon bushing which is then mounted in the plate. This bushing isolates the transducer electrically and also attenuates any high frequency vibrations set up in the plates by the blast.

For measuring side-on or incident pressures above the surface of the pad, pencil type probes are used. Currently, Model ST-7 probes manufactured by Susquehanna Instruments are used for these measurements. It has the same sensing element as the Model ST-2. Since these have to be pointed toward the blast to obtain accurate pressure readings, they cannot be used with confidence within the FAE cloud. This is because it is difficult to predict which direction the detonation wave will be traveling within the cloud and also because of the numerous reflections that usually occur behind the detonation wave in the cloud.

This uncertainty in detonation wave path or direction also introduces uncertainty into the pressure measurements made with the flush gages mounted under the cloud. The peak pressure measured will be influenced markedly by the incidence angle of the blast wave on the transducer. Depending on the component of the blast wave that is reflected, the peak pressure recorded can be several times the true side-on pressure. Therefore it is often difficult to apply meaning to peak pressures measured by transducers in contact with the cloud. The photographic coverage can often be a great help in interpreting the pressures recorded.

Before any test each pressure transducer, charge amplifier and recorder channel are calibrated by applying a known pressure to the transducer. A calibrator has been designed and built at NWC which can apply pressures up to 500 psi with rise times of 1 to 3 milliseconds. This method of calibration checks out and calibrates the complete instrumentation channel in one operation.

There are other measurements that can be made on fuel-air clouds. A couple that have been tried at CT-6 with limited success are temperature and concentration measurements. The problems here are transducer problems such as response time and ruggedness to withstand the environment.

Another facility at CT-6 that is being used extensively for FAE testing is the hot air balloon. This is a tethered balloon capable of lifting several hundred pounds. It is currently used to drop weapons from heights up to 1,000 feet. Pressure measurements have been made in the area under the balloon, but there is the practical problem of transducer placement. Since the impact point cannot be predicted with great accuracy, an array of transducers must be distributed throughout the impact zone. Thus only a few of them will be within a range that will give usable data on any given test.

A small, shallow man made "lake" has been constructed at CT-6. This was initially used for making static FAE shots over water but has since been used for dynamic testing. The test units were dropped from the balloon into the lake. The lake is approximately 150 feet square and 3 feet deep. The lake was constructed by scooping out a depression in the dry lake bed at CT-6. The water in the lake comes from ground water, the lake level representing the water table in that area.

The test procedure for one type of test conducted frequently at CT-6 will be given as an example. The objective of the test would be to measure the blast output of an experimental FAE device.

First, the position of the pressure transducers would be selected. These would be laid out in two gage lines extending radially from the device and 90 degrees apart. As an example, assume there are six gages in each gage line and that they are positioned 10, 15, 20, 25, 35 and 50 feet from ground zero. Then the peak overpressures anticipated at each transducer are estimated and used as a guide in calibrating the system. Again, as an example, assume peaks up to 400 psi are expected

at 10 and 15 feet, 300 psi at 20 feet, 150 psi at 25, 50 psi at 35 feet and 20 psi at 50 feet. These are given in Table D-1 along with the calibration pressures.

TABLE D-1. Anticipated Peak Pressures and Calibrations.

Gage	Range, ft	Peak, psi	Calibration, psi
1	10	400	400, 300, 200, 100
2	15	400	400, 300, 200, 100
3	20	300	320, 240, 160, 80
4	25	150	160, 120, 80, 40
5	35	50	60, 45, 30, 15
6	50	20	24, 18, 12, 6

The charge amplifiers are set up so that full scale output is approximately 125% of the peak pressure anticipated. Then each gage is calibrated by applying the appropriate pressures as given in Table D-1. The resulting charge amplifier outputs are recorded on the tape recorder and played back in the same manner as the actual test data, thus the whole data channel is calibrated at one time.

Since the pressure transducers used at CT-6 are reasonably linear in output, the four calibration points are used to fit the best straight line that passes through zero. The following equation is used to determine the overall data channel sensitivity.

$$\text{Sensitivity (volts/psi)} = \sum \frac{Pi\ Vi}{Pi^2}$$

where Pi and Vi are the pressure and the corresponding output voltage for each calibration step.

After each transducer is calibrated, it is placed in a Teflon bushing and then mounted at the proper range. The tape covering the nylon pressure plate of the transducer is examined and replaced if necessary. Prior to the actual test firing, the continuity of each channel is checked by tapping each transducer lightly and watching the output of the charge amplifier on an oscilloscope.

The cameras used to photograph the event are then mounted and loaded. These are usually Fastax cameras run at approximately 4000 frames per second. At least two cameras are used. One is supported by the poles above the pad for overhead coverage and the other is mounted off to the side to get a profile view of the cloud and detonation. This camera is mounted perpendicular to one of the gage lines. A third camera may be mounted perpendicular to the other gage line, as this type of back up data is often invaluable in interpreting the pressure data, or it may be set to get a close-up view of the initial dispersion process. All the Fastax cameras are equipped for applying a timing pulse once every millisecond on the edge of the film.

The experimental device is then set in place. It is usually mounted vertically on a light, four legged wooden stand. The stand should collapse easily under the forces generated by the dispersion charge so as to reduce its influence on the cloud formation process. The height of burst normally used is one half the expected cloud thickness.

If a self-contained cloud detonating device is used, this is all the setup that is required. If separate charges are used to initiate cloud detonation, these are placed at the desired position and connected to the firing circuit. Tetryl pellets taped to a wooden 2 x 2 foot stand are frequently used to initiate cloud detonation of experimental devices. Both the main dispersion charge and the cloud detonators are initiated with electric detonators such as the U. S. Engineers Special.

One precaution that is taken is to remove all unnecessary metal from the test site, or to use aluminum in place of iron or steel. This reduces the probability of burning the fuel-air cloud from sparks caused

by fragments striking metallic objects. Also, the cloud detonators and signal lines are positioned relative to the device so as to reduce the probability of being hit by fragments.

The actual firing is conducted from the control and instrumentation bunker. The start times for the cameras as well as the firing pulses to the dispersion charge and cloud detonator are programmed into the time-control unit. Either the firing pulse to the dispersing charge or the cloud detonator, or both, are recorded on one channel of the tape recorder. This signal is then used as a trigger pulse when playing back the transducer signals.

The signals recorded on the tape machine are played back into an oscilloscope and the resulting traces photographed. The arrival time of the blast wave at the gage can be determined as well as the pressure-time history at each gage.

2. TEST PROCEDURES

2.1 Introduction.

The air blast or shock wave that is produced by the detonation of a fuel-air explosive is similar to that produced by a solid explosive and the same techniques can be used to measure the blast waves from both types of explosives.

However, the detonation of a fuel-air explosive is the second step of a two step process. The first step is the generation of the fuel-air mixture. This may be done in several ways, but it is always a long process compared to the time it takes for the detonation to occur. For most fuel-air explosive bombs, this mixing of the fuel with the air is initiated upon contact with the ground surface or in close proximity to it. The downward velocity of the bomb, and therefore the fuel, can have a significant effect on the functioning of the bomb. This makes it essential that fuel-air explosive bombs be tested under dynamic conditions similar to what they will see in operational use.

Because of the technical difficulties and expense involved in obtaining good data in sufficient quantity under dynamic conditions, it is often desirable to conduct a complete series of static tests under optimum conditions; and then conduct only enough tests under dynamic conditions to determine if there is a significant difference between the static and dynamic test results. Generally, the static tests can be optimized to give the maximum blast effect that can be expected from a given design. The dynamic tests are needed only to determine if and to what degree the performance of the bomb is degraded under operational conditions.

2.2 Static Test Procedure.

To minimize interference with the shock wave, bomb blast tests should be conducted in a cleared, hard packed, flat area, large enough to hold all field instrumentation. Electrical lines and gages should be protected from fragments if necessary.

Due to the complex nature of the detonation process in the fuel-air explosive mixture, pressure transducers positioned within the detonating mixture do not give meaningful results unless they are omnidirectional. Generally, gages mounted flush with the surface under the detonating mixture are the only gages in contact with the mixture. These are exposed to a large thermal pulse and some type of thermal barrier may be required to separate the pressure pulse from the thermal pulse. Conventional blast gages may be placed at the ranges of interest outside the detonating mixture. At least two gage lines, 90 degrees apart, should be used.

High speed camera coverage is essential for a proper interpretation of test results. A framing rate between 2000 and 4000 frames per second is usually satisfactory. In addition, overhead camera coverage, while not necessary, can provide much data of value in interpreting the test results.

The bomb should be positioned vertically and at its designed stand-off distance.

If a fuel-air explosive detonates while the fuel-air mixture is in contact with the ground, a Mach stem may not form. If all or part of the fuel-air mixture is not in contact with the ground at the time of detonation, a Mach stem will form and care must be exercised when interpreting the data. It is almost impossible to predict the path of the triple point accurately since the fuel-air explosive type bomb has inherent variations in cloud shape and size.

2.3 Dynamic Test Procedure.

Several classes or levels of data can be obtained in these tests. The first or lowest class is to determine if the bomb functioned in such a manner that a detonation occurred. No attempt is made to obtain pressure-time data, only enough information is gathered to ascertain that a detonation did occur. Detonation velocity determinations from high speed photographic coverage will usually provide this information.

A second class of data would be to determine a certain portion of the pressure-time history, such as peak pressure or a characteristic impulse. Crude measures of these can usually be obtained with simple indicating devices such as the bikini gage or some land mine fuzes. While these have the advantage that they do not require electronic equipment, their usefulness for providing quantitative data is very limited. These and other types of simple indicating devices such as cantilever beams and collapsing cylinders should only be used for comparison to results obtained with these same devices under static test conditions. This requires that the indicating device used be calibrated as to functioning range in static tests prior to use in dynamic tests.

Impulse-sensitive rather than peak-pressure-sensitive indicating devices are more desirable since the impulse is more likely to change under dynamic conditions. The peak pressure obtained is largely a function of the fuel used, while the impulse depends on the geometrical shape of the fuel-air cloud as well as the peak pressure.

When testing larger sizes of fuel-air explosive bombs, BRL-type self recording gages may provide quantitative as well as qualitative data about the blast. However, because of their slow response time, the output of these gages should also be compared to results obtained under static test conditions.

The third, or highest level of data would be to determine the entire pressure-time histories with the same instrumentation system used in the static tests. Because of the uncertainty in knowing the impact point before the test, it is generally not feasible to use the same type of gage layout used in static tests. The gage layout used will depend on the accuracy with which one is able to predict the impact point and the number of gages available. Again, high speed camera coverage is an invaluable aid in interpreting the pressure-time data obtained.

If static test data are not available or are of poor quality, well instrumented dynamic tests are essential for the proper evaluation of an FAE bomb.

2.4 Data to be Obtained - Static Tests.

2.4.1 Test Item Data.

2.4.1.1 A general description of each test item. *This should include the description and nomenclature of the warhead and the explosive components.*

2.4.1.2 Test item weight.

2.4.1.3 Weights and types of explosive fill.

2.4.1.4 Height of burst or standoff.

2.4.1.5 Nominal time delay between initiation of mixing process and detonation.

2.4.2 Meterological Data.

2.4.2.1 Barometric pressure.

2.4.2.2 Temperature.

2.4.2.3 Relative humidity.

2.4.2.4 Wind direction and velocity at time of detonation. *Generally, test firings should not be made in winds greater than 10 knots.*

2.4.3 Pressure Data.

A pressure-time history should be obtained from each gage site.

2.4.4 Photographic Data.

2.4.4.1 Side view high speed photographic coverage of the mixing process and detonation.

2.4.4.2 Overhead high speed photographic coverage, if available.

2.4.5 Reflection Coefficient.

The reflection coefficient should be determined experimentally as often as changing soil conditions dictate.

2.5 Data to be Obtained - Dynamic Tests.

In addition to the data requirements listed under paragraph 2.4, the impact angle and velocity of the bomb should be determined.

The pressure-time data obtained will depend on the type of instrumentation used. The main requirement is that the data be obtained in a form that can be directly compared to data from static tests.

2.6 Data Reduction.

For effectiveness studies, the following air blast data are usually required.

a. Peak overpressure *(psi)*.

b. Positive impulse *(psi-msec)*.

c. Positive duration *(msec)*.

d. Typical pressure-time histories.

e. Any other data that may be needed to meet specific test objectives.

*TB 700-2
*NAVORDINST 8020.3
*TO 11A-1-47
DSAR 8220.1

DEPARTMENT OF THE ARMY TECHNICAL BULLETIN
DEPARTMENT OF THE NAVY PUBLICATION
DEPARTMENT OF THE AIR FORCE TECHNICAL ORDER
DEFENSE SUPPLY AGENCY REGULATION

EXPLOSIVES HAZARD CLASSIFICATION PROCEDURES

Departments of the Army, the Navy, and the Air Force, and
Defense Supply Agency, Washington, D.C.
19 May 1967

*This publication supersedes TB 700-2/ BUWEPINST 8020.3/TO 11A-1-47, 31 July 1962.

CHAPTER 1

INTRODUCTION

1-1. Purpose. This publication sets forth procedures for determining the reaction of ammunition, explosives, and solid propellants to specified initiating influences. Based on reactions obtained, it further provides for assignment of appropriate hazard classifications (Quantity-Distance Class, Storage Compatibility Group, ICC Class and ICC Markings). It also specifies tests from which required safety distances for single and multistage solid propellant systems may be determined. It seeks to assure that under identical conditions all DOD Components* and other involved Government agencies will use identical hazard classifications for ammuition, explosives, and solid propelant items.

1-2. Division of Criteria. The procedures are divided into five chapters as follows:

a. Chapter 1—provides general information as to the use, application, and limitations of the procedures.

b. Chapter 2—provides general information, establishes responsibility, and prescribes administrative procedures for processing determinations of hazard classification information.

c. Chapter 3—establishes minimum test criteria for explosives compositions and solid propellant compositions.

d. Chapter 4—establishes minimum test required as a basis for determination of hazard classification information of ammunition items including rocket motors and rocket ammunition up to 8-inch diameter.

e. Chapter 5—establishes minimum tests required as a basis for determination of safety distances for items containing solid propellants.

1-3. Use of the Procedures. Procedures herein will be included in any test plan which is developed by the responsible DOD Component* for a specific item to be tested. They are to be considered as a minimum with regard to the type and number of tests. Additional tests, both in number and type, may be conducted as desired by the responsible DOD Component.

1-4. Application to Existing Items. Tests may be performed on existing items at the discretion of the responsible DOD Component when adequate information is not available to properly classify the item.

1-5. Hazards Not Determined by These Criteria. During the development of these procedures, all types of hazards were considered, however, tests are not included to specifically determine the following:

a. Hazards.

(1) From toxic, biological, or radioactive sources.

(2) During various stages of manufacture and assembly.

(3) From flight range of guided missiles or rockets in launch configuration.

(4) Associated with launching of a vehicle or tactical missile.

b. Susceptibility to Accidental Initiation by Electrostatic and Electromagnetic Influence.

*See appendix B.

CHAPTER 2

GENERAL

2–1. Introduction. This chapter provides general information as to applicability and responsibility, and administrative procedures in processing determinations of hazard classification information.

2–2. Procedure. *a.* The DOD Component sponsoring development, or first adopting for use an explosive item or assembly will be responsible for assigning the appropriate hazard classification (Quantity-Distance Class, Storage Compatibility Group, ICC Class and ICC Markings). As a basis for this action, the DOD Component will perform tests in accordance with this document or will establish analogies with other items that have been properly classified.

b. The responsible DOD Component will notify the addressees listed in paragraph 2–3 of hazard classifications being assigned. Documentation to support these classifications will be furnished where major items such as rocket motors and systems are involved or where any of the listed addresses are known to have special interest in the item involved. Otherwise, documentation will be furnished only upon request.

c. Upon receiving notification of a hazard classification assignment that is considered incorrect, a Military Department will advise the responsible DOD Component within 30 days of its nonconcurrence. The Armed Services Explosives Safety Board (ASESB) will resolve differences which cannot be resolved by the DOD Components concerned.

d. The hazard classifications assigned will be provided to the MTMTS for transmittal to the ICC with the statement that assigned classifications have been concurred in by the Military Departments. Such correspondence will be addressed as shown in paragraph 2–3.

e. The responsible DOD Component should notify other components and agencies of significant tests that are pending and afford them the opportunity to observe the conduct of these tests.

f. When cases arise which require special considerations, or when the test requirements of this document cannot be met for a specific item, the responsible DOD Component will coordinate with the ASESB to develop appropriate test criteria for the case in question.

2–3. Notification of Classifications. *a.* The DOD Component responsible for determining the hazard classifications will furnish notifications of classifications assigned (and where appropriate supporting documentation) to the following:

(1) *For concurrence.*

	Number of Copies
Deputy The Inspector General for Inspection and Safety, USAF ATTN: AFIAS-G2 Norton AFB, Calif. 92409	6
U.S. Army Materiel Command Department of the Army ATTN: AMCAD-S Washington D. C. 20315	4
Commander, Naval Ordnance Systems Command Department of the Navy (ORD-932) Washington, D. C. 20360	3

(2) *For information.*

Chairman Armed Services Explosives Safety Board Department of Defense Washington, D. C. 20315	1
Headquarters, U.S. Coast Guard ATTN: Hazardous Cargo Division Washington, D. C. 20226	1

	Number of Copies
Headquarters National Aeronautics & Space Administration ATTN: Safety Director (Code BY) Washington, D. C. 20546	2

(3) *For transmittal to ICC.*

Headquarters Military Traffic Management & Terminal Service ATTN: MTMTS–PM Washington, D. C. 20815	1

b. Documentation of tests referred to in paragraph 2–2*b* will include the following information, as applicable:

(1) *Preliminary data.*

(*a*) Item designation (and Federal stock No. if available).

(*b*) Item lot number.

(*c*) Item sublot number.

(*d*) Item serial number.

(*e*) Detailed quality control report on location and size of defects if any, in test item.

(*f*) The following additional information will be included in reports of tests conducted under chapter 5:

1. Propellant type, designation and all ingredients in percent by weight.

2. Propellant lot number.

3. Propellant batch number.

4. Propellant grain serial number.

5. Propellant weight before test.

(*g*) Date of manufacture of item.

(*h*) Date of test.

(*i*) Type of pretest treatment (temperature conditioning, etc.).

(*j*) Meteorological data.

1. Ambient air temperature.*

2. Barometric reading.*

3. Wind velocity and direction.*

4. Relative humidity.*

5. Adiabatic chart.*

6. Upper air chart.**

(2) *Test data.*

(*a*) Schematic drawings and photos of test setup prior to test showing location, type, and distance of—

1. Instrumentation.

2. Cameras.

3. Donor.

(*b*) Photos of the actual test items in the test configuration and photographs of the test position after firing.

(*c*) Profile ground elevation map of test area out to and including the .2 psi overpressure point or maximum fragmentation distance, whichever is greater. The profiles will be 90° apart, and for horizontally oriented items, paralled to and perpendicular to the axis of the test item.*

(*d*) Reproductions of all pertinent original recorded data and related calibrations.

(3) *Reduced data.*

(*a*) Overpressure in psi and impulse vs distance curve (including calibration test).*

(*b*) Fireball radius as a function of time.*

(*c*) A map locating the radial and angular positions of unexploded items, metal fragments, and propellant fragments (burned and unburned) with respect to the test position. Fragment type and etestimated weight will be indicated.

(*d*) Crater dimensions.

2–4. Instrumentation. In order to properly interpret test results, instrumentation of various types must be used when conducting tests under chapter 5. Gages for recording overpressure and impulse will be provided for tests in paragraphs 5–8, 5–10, and 5–11. Photographic coverage will be provided for all tests. Instrumentation to be used is as follows:

a. Blast overpressure gages used for measuring side-on overpressure must be capable of recording the complete pressure-time history of the shock wave, so that both peak pressure and impulse data can be obtained. A minimum

*To be taken at test site for all tests under chapter 5.
**To be taken at nearest weather station for all tests over 25,000 pounds.

of 14 gages are required and will be arranged in two radial arrays (one parallel to the long axis of the test item and the other 90° to this, at the center of the test item, for testing in vertical position, two radial arrays at 90° to each other). These gages should be placed to record expected overpressures of 80, 20, 10, 5, 1, 0.5, and 0.2 psi. Prior to conducting the test, the gages must be calibrated. Wherever possible, calibration will be by at least two methods; one of which will consint of detonating a known quantity of high explosives in the approximate location where the test item is to be placed. The results of the calibration tests are to be included with the test report. Gages of proven reliability and in common use will be used. In those cases which deviate from this guidance, the gages will be calibrated in such a manner that results can be correlated with results achieved by other operators using different systems.

b. Color motion picture coverage of tests under chapter 5 will be as follows:

(1) A minimum of two documentary cameras at 16 or 24 frames per second for all tests under chapter 5.

(2) A minimum of two high speed cameras at 4,000 frames per second, viewing the test from at least two directions for tests in paragraphs 5–8, 5–10, and 5–11. Timing will be included on all high speed film using the test initiation sign as a base line. Such motion picture coverage will be provided in other tests if essential to the evaluation of test results.

(3) Still photographs will be taken of the test setup before and after all tests.

c. Instrumentation to measure fireball temperature and radiant heat, and where feasible, heat absorption representative materials. This instrumentation will be provided where it is feasible and where useful data can be obtained.

Warning: During all the test phases, extreme caution will be observed. Strict safety procedures will be enforced.

Note. The suggested procedures for initiating fires may be modified if they do not alter the test results.

CHAPTER 3

MINIMUM TEST CRITERIA FOR BULK EXPLOSIVE COMPOSITIONS AND SOLID PROPELLANT COMPOSITIONS

3–1. Introduction. *a.* Tests in this chapter are intended to develop data on the stability and sensitivity of new compositions of bulk explosives and solid propellants. Such data is required in order to determine that these compositions are safe to handle, transport, and store.

b. These tests are conducted on laboratory samples of material. The sample weights or dimensions listed are the minimum upon which conclusions may be drawn; however, it is suggested that smaller samples be tested to give preliminary indications of the hazards to be encountered.

3–2. Scope. This chapter includes those tests required to assign hazard classifications for transportation of the bulk composition. These tests must be conducted prior to shipment in commerce of any explosive or propellant composition other than "Laboratory Samples" as specified by current ICC Regulations.

3–3. Classification of End Items. Procedures in chapters 4 and 5 must be followed in the assignment of the transportation and storage classifications to end items containing the explosive or propellant composition except when an analogy can be established with other items that are properly classified and identified.

3–4. Recording of Data. The results of tests performed under this chapter are to be recorded in a manner similar to that shown in figure 1.

3–5. Instrumentation. Due to the limited quantity of material involved in these tests, instrumentation to record peak pressure, impulse, and temperature as well as high speed photography may be eliminated.

3–6. Equipment. The following equipment is required for tests under this chapter:

a. One Bureau of Explosives impact apparatus. Drawings are available at the Bureau of Explosives, Association of American Railroads, 63 Vesey Street, New York, N. Y., 10007.

b. One ventilated explosionproof oven capable of maintaining a temperature of 75°C or above for a period of 48 hours. The oven will be equipped to continuously record the temperature. Dual devices for control of temperature should be provided.

c. Number 8 electric blasting caps or caps of equivalent strength as required. A number 8 blasting cap is defined by ICC as one containing 2 grams of a mixture of 80 percent mercury fulminate and 20 percent potassium chlorate.

d. One blasting machine or equivalent for initiating electric blasting caps.

e. Kerosene-soaked sawdust sufficient for three beds, 1-foot square and ¼ inch thick.

f. Electric match-head igniters as required.

g. Solid lead cylinders 1½-inch diameter by 4 inches high as required.

h. One piece of mild steel plate SAE 1010 to 1030, ½ inch thick by 12 inches square.

i. Mild steel plates (SAE 1010 to 1030) 6 inch x 6 inch x ⅜ inch as required.

j. Tubing, steel, cold drawn seamless, mechanical, composition 1015, 1⅞ inch-OD, 0.219 inch-wall thickness variations ± 10 percent acceptable by 5½ inches long as required.

k. Cellulose acetate, or equivalent, cards, 2 inch diameter by 0.01 inch thick as required.

l. Wire (demolition cable) as required for connecting blasting machine to electrically initiated items.

m. Engineers special electric blasting caps (J–2) as required.

3–7. Test Samples. The following test samples are required for this chapter:

a. Twelve samples 2±¼-inch cubes.

Date _____

Sponsoring Agency _____

Contract No. _____

Propellant Identity (Type No.) _____

Propellant Spec. _____ Batch _____

Mfg. Date _____

Detonation Test

	Exploded		Burned		Fragmented	
	Yes	No	Yes	No	Yes	No
No. 8 Blasting Cap Test I	___	___	___	___	___	___
Test II	___	___	___	___	___	___
Test III	___	___	___	___	___	___
Test IV	___	___	___	___	___	___
Test V	___	___	___	___	___	___

Samples: Five 2-inch cubes. Test: One blasting cap per sample.

Ignition & Unconfined Burning Test

	Exploded		Average Burning Time
	Yes	No	Seconds
One 2-inch cube	___	___	_____
One 2-inch cube	___	___	_____
Four 2-inch cubes	___	___	_____

Samples: Six 2-inch cubes. Test: Ignite & burn unconfined

Thermal Stability Test

	Explosion		Ignition		Change in Configuration	
	Yes	No	Yes	No	Yes	No
One 2-inch cube	___	___	___	___	___	___

Samples: One 2-inch cube Test: 48 hours at 75° C. in vented oven.

Card Gap Test 50% Value (No. of Cards)

Impact Sensitivity Test

Bureau of Explosives Impact Apparatus

Ten 3¼" (± 1/16") Drop Test 10 Trials			Ten 10" (± 1/16") Drop Test 10 Trials		
No. of Trials Exhibiting			No. of Trials Exhibiting		
Explosion Flame and Noise	Decomposition Smoke No Noise	No Reaction No Smoke No Noise	Explosion Flame and Noise	Decomposition Smoke No Noise	No Reaction No Smoke No Noise

Approved:

Test Director _____ Test Department Head _____

Assigned Classification	
ICC Forbidden	
ICC Restricted*	
ICC Class A	
ICC Class B	

DOD Approval

Signature _____

Title _____

Organization _____

*Shipping Instructions are to be requested from ICC (para 3-13a(2).

Figure 1. Sample summary data sheet.

b. Ten 10 mg (approx) samples suitable for use in the Bureau of Explosives impact apparatus (0.20 in. ± .02 in. diameter x 0.10 in. ± .02 in. long).

c. 2-inch diameter by 1-inch long pressed pentolite pellet, Federal stock No. 1375–991–8891 as required (para 5–1*e*).

d. Samples sufficient to fill 12 each of item 3–6*j* above (para 3–12*a*(2)).

3–8. **Detonation Test.** *a.* Place one lead cylinder (3–6*g*) upon the steel plate (3–6*h*). Place a No. 8 blasting cap (3–6*c*) perpendicular to and in contact with a flat surface of the 2-inch cube sample (3–7*a*) which is then placed on top of the lead cylinder. A 2-inch diameter wood block with a hole drilled in its center similar to that shown in figure 2 may be used for positioning the blasting cap. Deformation (mushrooming) of the lead cylinder will be considered as evidence of detonation. Conduct this test a minimum of five times, or until detonation occurs, whichever is the least number of tests.

b. Data from this test will be recorded under Detonation Test.

3–9. **Ignition and Unconfined Burning Test.** *a.* Place a 2-inch sample (3–7*a*) on a bed of kerosene-soaked sawdust (3–6*e*), and ignite the sawdust with an electric match-head igniter (3–6*f*). Perform this test twice.

b. Place four 2-inch (3–7*a*) samples end-to-end in a single row in contact with each other on a single bed of kerosene-soaked sawdust (3–6*e*) and ignite the sawdust with an electric match-head igniter (3–6*f*) at one end.

c. Record results under Ignition and Unconfined Burning Test.

3–10. **Thermal Stability Test.** *a.* Place one 2-inch sample (3–7*a*) in constant temperature explosionproof oven (3–6*b*). Raise the temperature of the oven to 75°C. and maintain the temperature at 75°C. for a period of 48 hours. These temperatures will be continuously recorded. Constant observation is not required.

b. Record results under Thermal Stability Test.

3–11. **Impact Sensitivity Test.** *a.* Conduct ten individual tests using one sample (3–7*b*) per test in the Bureau of Explosives impact apparatus (3–6*a*).

b. The sample (3–7*b*) is placed in the cup assembly, the weight is then dropped from the desired height (i.e., 3¾ or 10 in.) Observe results to supply data as required under Impact Sensitivity.

c. Use cleaning equipment as required to thoroughly clean and dry the anvil and cup assemblies of the impact apparatus prior to each test. Apparatus must be at ambient temperature (room temperature) 25°C. ± 5° prior to each test.

d. Check that the equipment is properly leveled and replace the tools when worn.

3–12. **Card Gap Test.** *a.* Materials required for each test are as follows:

(1) One each tubing (3–6*j*).
(2) Sample (3–7*d*) cast into or machined to fit into above tubing.
(3) Two pentolite pellets 2-inch diameter by 1 inch long (3–7*c*).
(4) One Engineers Special Blasting Cap J–2 (3–6*m*).
(5) One steel plate 6 inch x 6 inch x ⅜ inch (3–6*i*).
(6) Cellulose acetate, or equivalent, cards 2-inch diameter x 0.01 inch thick (3–6*k*).
(7) Four pieces of plastic material 1/16 inch x ½ inch x ½ inch.

b. Test configuration. The components of the test are arranged in the following manner. The witness plate is supported on two edges parallel to and approximately 6 inches above the ground surface. Four small pieces of material 1/16 inch x ½ inch x ½ inch are placed on the plate to support the pipe containing the test sample, and maintain the 1/16 inch air gap, which should not overlap onto the propellant or explosive. The air gap between the acceptor and witness plate should be free of solid material. The test sample is to be located approximately in the center of the witness plate. The pentolite booster is then placed on top of and in contact with the sample at the top of the pipe and the J–2 blasting cap attached. The arrangement of components for this test is similar to that shown in figure 2 except the cellulose acetate cards and the cardboard tube are omitted in this test. Detonation is indicated when a clean hole is cut in the witness plate. The test sample and explosives booster are to be at a temperature of approximately 25°C. ± 5° at time of test. Should no detonation occur in the

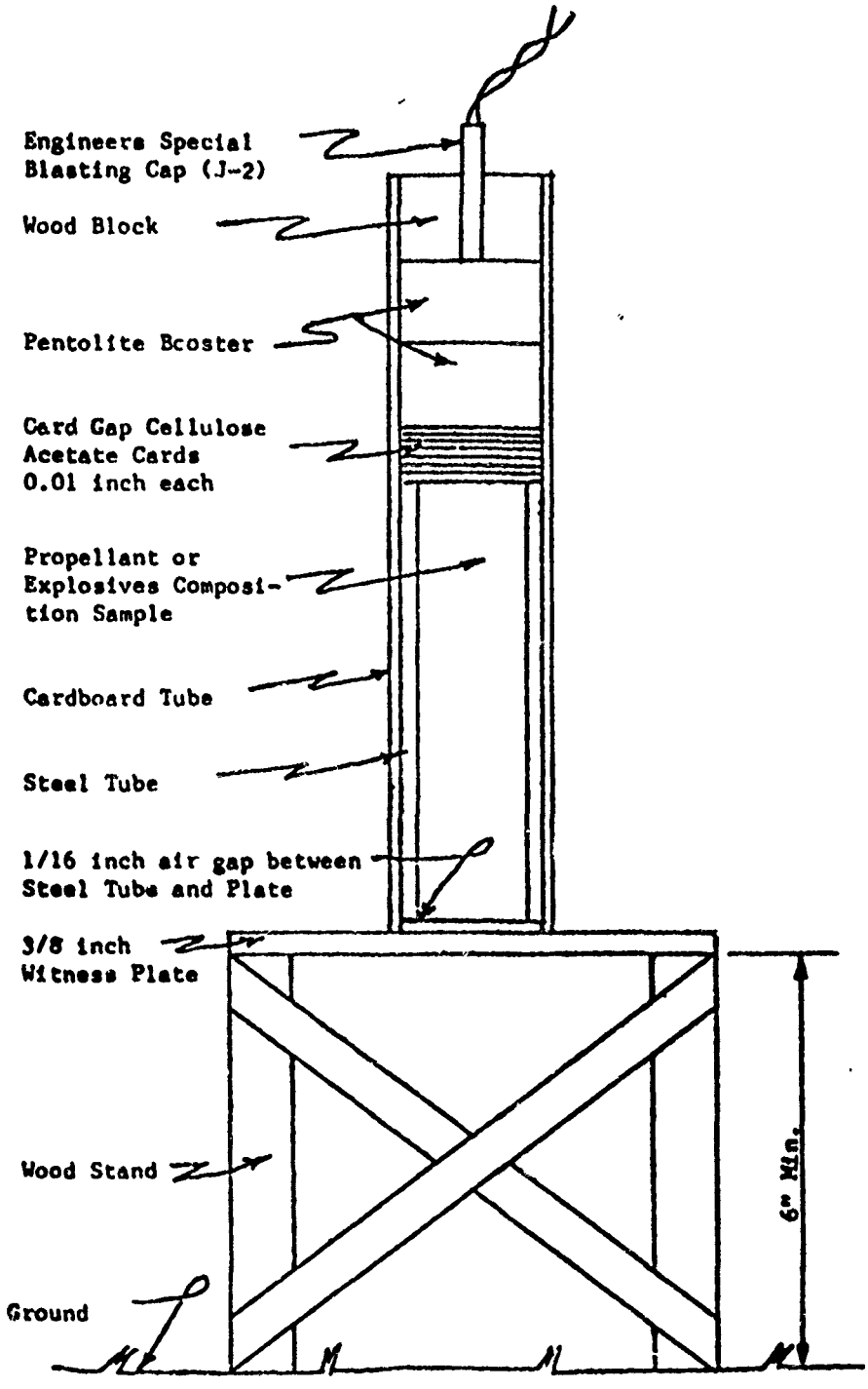

Figure 8. Setup for card gap test.

first test, it will be repeated two times for a total of three tests. If detonation occurs, proceed to paragraph 3–12c.

c. The following tests are to be performed when the test sample detonates in the above tests (3–12*b*). If no detonation of the test sample occurs in the above tests, this test will not be performed.

(1) The test samples, high explosive boosters and witness plates used in these tests are as given in paragraph 3–12*a* above. The attenuation cards used are 0.01-inch cellulose acetate sheet or equivalent (3–6*k*). These tests are to be conducted with the test sample and booster at a temperature of approximately 25°C. ± 5° throughout. The test setup is as shown in figure 2. The cellulose acetate cards should be held firmly but not pressed.

(2) The first test to be performed will utilize 8 cards; if a detonation occurs, the number of cards will be doubled (i.e., 16 cards) for the second test. If no detonation occurs reduce the number of cards by one-half (i.e., 4 cards). Doubling of the number of cards will be continued in succeeding tests until no detonation occurs. When a number of cards is reached that prevents detonation, the next test will be with the number of cards reduced by half the preceding increment of increase (i.e., if detonation occurs at 32 cards but not at 64 cards, the next test will be with 48 cards). If detonation occurs at the reduced number of cards (48 cards in the example cited above) the number of cards in the next test will be increased by one-half the preceding increment (i.e., from 48 to 56 cards), etc. This procedure will be followed until the point of 50 percent probability of detonation is obtained. If the card gap sensitivity of a similar propellant or explosive composition is known, testing should begin at approximately that number of cards.

(3) Detonation is indicated when a clean hole is cut in the witness plate. The measure of charge sensitivity is the length of attenuation (gap length) at which there is 50 percent probability of detonation according to the above criterion. The charge sensitivity will be expressed in terms of number of 0.01-inch cards necessary for the 50 percent value between detonation and no detonation. Normally, a maximum of 12 tests will be required to determine the 50 percent value. (See A–9, appendix A.)

3–13. Interpretation of Results. *a.* For ICC and military purposes, results of chapter 3 tests will be interpreted as follows:

(1) ICC "Forbidden" if the following occurs: Thermal stability test results in either an explosion, burning, or marked decomposition of the sample.

(2) ICC Restricted. Compositions with an explosive impact sensitivity of less than 4 inches of drop height (3–11) will not be shipped until shipping instructions have been requested and received from the Interstate Commerce Commission.

(3) ICC Class A–(Military Class 7) if one or more of the following occur:

(*a*) Detonation and card gap tests have determined a detonation sensitivity value of 70 or more cards.

(*b*) Impact sensitivity test produces an explosion above 4-inches of drop height.

(*c*) Ignition and unconfined burning test produces a detonation.

(4) ICC Class B–(Military Class 2) if all of the following occur:

(*a*) Ignition and unconfined burning tests did not result in an explosion.

(*b*) The Thermal Stability Test did not result in an explosion, burning, or marked decomposition.

(*c*) Detonation and card gap tests have indicated a detonation sensitivity value of less than 70 cards or no reaction at zero cards.

CHAPTER 4

MINIMUM TEST CRITERIA FOR AMMUNITION AND EXPLOSIVES ITEMS INCLUDING FUZES, IGNITERS, MAIN EXPLOSIVE CHARGES, GUN TYPE PROPELLANTS, ARTILLERY AMMUNITION, PYROTECHNICS, ROCKET MOTORS AND ROCKET AMMUNITION UP TO 8 INCHES DIAMETER

4–1. Introduction. The tests in this chapter are intended to develop data upon which storage and transportation classifications of ammunition items may be based. Rocket motors and devices, containing solid propellant, except as indicated, are to be tested in accordance with chapter 5. The following test criteria will be used in the development of test operational plans for indicated ammunition items.

4–2. Number of Tests. Tables 1 through 4 indicate the minimum tests to be conducted, however, additional tests should be performed when a greater level of confidence is required for specific applications.

4–3. Use of Additional Items in Tests. Many of the items to be tested under this chapter will be suitable for inclusion in storage hazard classes 3 through 6 which are based upon fragment dispersion. The number of containers of items specified for the external heat test in tables 1 through 4 are the minimum upon which the classification may be based. However, in order to improve the statistical value of these tests and to more accurately predict results of accidents under actual storage conditions, the number of containers used in this test should be increased whenever possible.

4–4. Tests in Storage and Shipping Containers. All tests under this chapter are to be conducted on items in standard storage and transportation containers. Should items be stored or shipped in more than one type of container, the test series must be conducted on each type of container (i.e., wood vs. metal). Classifications will then be assigned to the item in each type of container.

4–5. Description of Tests. In the performance of tests given in tables 1 through 4, the following will apply:

a. Detonation "Test A" (propagation within a container).

(1) This test is to be conducted on items which are packaged with more than one item in the standard storage and shipping container to determine if functioning of one item will cause other items in the container to function.

(2) The most centrally positioned item within the package will be primed as required in the applicable table.

(3) The primed item will be fired from a safe location. The results of the test will be documented as required by paragraphs 2–3*b*(1), 2–3*b*(2)(*b*), 2–3*b*(3)(*c*), and 2–3*b*(3)(*d*).

(4) Test A will be conducted the specified number of times, or, until communication to adjacent items occurs, whichever is less.

b. Detonation "Test B" (propagation between containers).

(1) This test is to be conducted to determine if the functioning of items in one container will cause functioning of items in adjacent containers.

(2) If the detonation "Test A," above resulted in no communication within the container or the outside container was not ruptured, these tests ("Test B") may be omitted.

(3) The item in the donor container to be primed and boostered in accordance with tables 1 through 6 is that which is closest to explosives in the acceptor container. This should assure subjection of acceptor explosives to maximum blast effects from donor material.

(4) The acceptor container will be positioned in a manner which provides the minimum separation between the explosive components in the two containers (i.e., container of fuzes with boosters will be arranged so that the boosters in one box are immediately beneath those above, and the lower box will be inverted in order to have minimum separation distance between the boosters).

(5) The primed item will be fired from a safe location. The results of the test will be documented as required by paragraphs 2–3*b*(1), 2–3*b*(2) (*b*), 2–3*b*(3) (*c*) and 2–3*b*(3) (*d*).

c. External Heat "Test C" (open fire). This test is designed to simulate a condition where the containers of explosive items are completely enveloped in a hot fire. Tables 1 through 6 require that more than one outer shipping container be used in this test. They should be arranged in a compact stack, approximating a cube, if possible. This stack should then be secured with steel bands in two directions. These steel bands are intended to maintain stacking until initiation of one or more items occurs. They must be incapable of significantly affecting dispersal of fragments. The stack of containers will then be placed on a crib of sufficient dimensions to hold the stack of containers and approximately 30 inches high. The interior of the crib is to be filled with combustible material such as scrap lumber. The crib and the stack of items to be tested are then covered with additional combustible material, such as scrap lumber, sufficient to insure a sustained hot fire. The entire mass is then to be saturated with approximately 50 gallons of JP–4 or diesel fuel and ignited by such means as an electric squib and 2 ounces of smokeless powder. In order to reduce the effects of wind direction, it is advisable to ignite the pile in two places preferably on opposite sides. Still photographs will be taken before and after the test. Photos after the test will clearly show results of the test. Resulting fragments and missiles will be identified and their location with respect to the test position recorded.

d. Where sand filled containers are specified for confinement in tests B and C, they will be of the same material as the containers of the items being tested. The sides and top of the container to be tested will be completely inclosed by the sand filled containers in order to provide confinement similar to a central container in a large stack of containers.

Table 1. Minimum Test Criteria For Determining Hazard Classification of Fuzes

(Including projectile type, rocket, missile, hydrostatic, torpedo exploder mechanisms, safe and arming devices, and initiating devices of all types)

1. Packaging	*2. Type of Info To Be Determined by Test*	*3. Types of Initiation To Obtain Info Outlined in Item 2*
With Booster Assembled	Type of Propagation Within 1 Container	Detonation
Without Booster	Type of Propagation from 1 Container to Another	External Heat
Without Booster, but Booster Packed in Same Container	Determination of Fragment Hazard	

4. Minimum Test Criteria

Type test	*Number items per test*	*Number of tests*	*Primer*	*Booster*	*Confinement*
Test A. Detonation	1 Shipping Container	5	Engr Special Blasting Cap	None	Sand Filled Containers
Test B. Detonation	2 Shipping Containers	5	Engr Special Blasting Cap	None	Sand Filled Containers
Test C. External Heat	6 Shipping Containers	1	None	None	Steel banded

Table 2. Minimum Test Criteria for Determining Hazard Classification of Igniters

(Including rocket and missile, gun type, etc.)

1. *Type*	2. *Packaging*	3. *Type of Info To Be Determined by Test*	4. *Types of Initiation to Obtain Info Outlined in Item 3*
Electric	1 Per container	Type of Propagation Within 1 Container	Simple Ignition, or Detonation, as Appropriate
Friction	More than 1 Per Container		
Percussion		Type of Propagation from 1 Container to Another	External Heat
Combination of Any of Above		Determination of Fragment Hazard	

5. *Minimum Test Criteria*

Type test	*Number items per test*	*Number of tests*	*Priming*	*Booster*	*Confinement*
Test A. Detonation	1 Shipping Container	5	Engr Special Blasting Cap	None	Sand Filled Containers
Test B. Detonation	2 Shipping Containers	5	Engr Special Blasting Cap	None	Sand Filled Containers
Test C. External Heat	6 Shipping Containers	1	None	None	Steel Banded

Table 3. Minimum Test Criteria for Determining Hazard Classification of Main Explosive Charge

(Including projectiles, mines, depth charges, rifle and hand grenades, bombs, and demolition explosives)

1. *Type*	2. *Type of Info To Be Determined by Test*	3. *Types of Initiation To Obtain Info Outlined in Item 2*
Warhead, Less Fuze	Propagation from 1 Container to Another	Explosive Priming
Warhead, Plus Fuze		
(1) Attached	Separation Distance from 1 Item or Stack to Another to Prevent Propagation	External Heat
(2) Unattached, but in Same Container	Determination of Fragment Hazard Determination of Blast Hazard	

4. *Minimum Test Criteria*

Type test	*Number items per test*	*Number of tests*	*Priming*	*Booster*	*Confinement*
Test A. Detonation	2 Shipping Containers (Side-by-Side)*	5 -- Or Until First Detonation of Both	Engr Special Blasting Cap	30 Gram Tetryl** or Equivalent (Fuze Booster-When Attached)	None
Test B. Detonation	2 Shipping Containers (Separated 50 inches)*	3 Det of Primed Container Only	Engr Special Blasting Cap	30 Gram Tetryl** or Equivalent (Fuze Booster-When Attached)	None
Test C. External Heat	2 Shipping Containers	1	None	None	Steel Banded

*Projectiles not normally boxed for storage or shipment will be tested with a minimum of 2 stacks, each containing not less than 15 projectiles. Stacks to be separated 50 inches nose-to-nose-base-to-base.

**Pressed pellet approximately 1 inch-diameter x 1½ inch-long at density of 1.5.

Table 4. Minimum Test Criteria for Determining Hazard Classification of Gun Type Propellants for Cannon, Gun, Tube Mortar, and Rocket Motors up to 8-Inch Diameter

1. Type	2. Type of Info To Be Determined by Test	3. Types of Initiation To Obtain Info Outlined in Item 2
Gun Type Propellants for Cannon, Gun Tube Mortar or other Cartridge Actuated or Launching Devices in Bulk, Bags and Cartridge Cases (1) Single Base (2) Double Base (3) Triple Base	Liability to Detonation in Approved Bulk Storage and Shipping Containers (1) Bulk Propellant in Storage and Shipping Containers (2) Loaded in Finished Items Type of Propagation Within 1 Container Type of Propagation from 1 Container or Item to Another Determination of Fragment Hazard of Finished Items Determination of Blast Hazard	Simple Ignition External Heat Explosive Priming

4. Minimum Test Criteria for Bulk Propellant

Type test	Number items per test	Number of tests	Priming	Booster	Confinement
Test A. Detonation	1 Shipping container	5	Electric Squib*	2 Oz Black Powder	Sand Filled Containers and Steel Straps
Test B. Detonation	2 Shipping Containers	1	Electric Squib*	2 Oz Black Powder	Sand Filled Containers and Steel Straps
Test C. External Heat	6 Shipping Containers	1	None	None	Steel Banded

5. Minimum Test Criteria—Finished Items

Type test	Number items per test	Number of tests	Priming	Booster	Confinement
Test A. Detonation	1 Shipping Container	Not Less than 3	Engr Special Blasting Cap	30 Gram Tetryl**	None
Test B. Detonation	2 Shipping Container	Not Less than 2***	Engr Special Blasting Cap	30 Gram Tetryl**	Sand Filled Containers
Test C. External Heat	6 Shipping Container or Item	1	None	None	Steel Banded

*Squib to be placed 4 inches from bottom of can and all cans to be standing vertical.
**Pressed pellet approximately 1 inch-diameter x 1¼ inch-long at density of 1.5.
***Not to be conducted if no detonation occurs in Test A—then Test A to be conducted 6 times.

Table 5. Minimum Test Criteria for Determining Hazard Classification of Gun, Howitzer, Mortar, and Recoilless Rifle Ammunition and Rocket Ammunition Complete Rounds (Assembled or Unassembled) up to 8-Inch Diameter

1. Type	2. Packaging	3. Type of Info To Be Determined by Test	4. Types of Initiation To Obtain Info Outlined in Item 3
Complete Rounds, Fixed Semifixed Separated Loading In Same Package	1 Round Per Container More than 1 Round Per Container	Propagation within a Single Container Propagation from 1 Container to Another Determination of Contribution of Propellant to HE Charge in 1 Package Determination of Fragment Hazard Determination of Blast Hazard	Simple Ignition Detonation External Heat

5. Minimum Test Criteria

Type test	Number items per test	Number of tests	Priming	Booster	Confinement
Test A. Detonation of Projectile or Head	1 Item	5 Complete Units	Engr Special Blasting Cap or Normal Fuze Train Armed	30 Gram Tetryl*	Sand Filled Containers
Test B. Detonation of Projectile or Head	2 Shipping Containers	5	Same as Above	30 Gram Tetryl*	Sand Filled Containers
Test B. Detonation	2 Shipping Containers or 2 Stacks with 12 Items Each Separated 50 inches Nose-to-Nose, Base-to-Base, or as Stored	5	Same as Above	30 Gram Tetryl*	Same as Above
Test C. External Heat	6 Shipping Containers	1	None	None	Same as Above
Test C. External Heat	6 Shipping Containers	1	None	None	None

*Pressed pellet approximately 1 inch-diameter x 1½ inches long at density of 1.6.

Table 6. Minimum Test Criteria for Determining Hazard Classification of Pyrotechnics —All Types and Certain Small Items Containing Solid Propellants (Para 5-3d)

1. Type	*2. Packaging, as Normally Store and Shipped*	*3. Type of Info To Be Determined by Test*	*4. Types of Initiation To Obtain Info Outlined in Item 3*
Burning	Individual Item or Unit	Propagation Within a Single Container	Simple Ignition
Detonating	More Than 1 Item Per Unit	Propagation from 1 Container to Another	Detoration
		Determination of Fragment Hazard	External Heat
		Determination of Blast Hazard	
		Determination of Fire Dispersement Hazard	

5. Minimum Test Criteria

Type test	Number items per test	Number of tests	Priming	Booster	Confinement
Test A. Detonation	1 Container	5	Normal Means of Ignition or Engr Special Blasting Cap	None	None
Test B. Detonation	2 Containers	5	Same as Above	None	None
Test C. External Heat	1 to 6 Containers Depending on Size of Unit	1	None	None	Steel Banded

CHAPTER 5

MINIMUM TEST CRITERIA FOR ROCKET MOTORS OR DEVICES CONTAINING SOLID PROPELLANTS

5–1. Introduction. *a.* The tests in this chapter are designed to furnish data on the hazard characteristics of assembled items upon which quantity-distance criteria may be based. They are intended to interrelate the effects, in the expected environment, of—

(1) The functioning of an individual item on like items when stored in quantity, or

(2) The functioning of a single item on the remaining portions of a complete configuration.

(3) The functioning of destruct system on a motor at ambient temperature or when a motor is being fired.

b. The following tests are included in this chapter:

(1) Susceptibility of end item to external detonation.

(2) Detonation effects of one item upon like items.

(3) Detonation effects of one stage of a missile on the remaining stages of the same missile.

(4) Effects of warhead detonation on the propulsion stages.

(5) Effects of destruct system on motors.

c. Tests are not given to specifically determine the hazard classification of items under conditions peculiar to combat usage or when items are tactically or strategically deployed. (In the case of solid propellant missiles, certain tests are given which may be used to determine the hazard characteristics of assembled missiles. These results may be used for siting flight test stands or tactical siting of assembled missiles. However, other types of test data or hazard criteria may be the controlling factor in the determination of the proper siting of the missile.)

d. Reject motors or devices may be used in this phase of testing if reasons for rejection will not materially affect the test results. Prior approval for use of reject motors or devices must be obtained from the responsible DOD Component. Request for approval to use reject motors or devices will state the basis upon which the item was rejected.

e. Certain standard pentolite donor charges are available to DOD Components, other Government agencies and their contractors for conducting the tests described herein. They can be obtained from: Ships Parts Control Center, U.S. Naval Supply Depot, Mechanicsburg, Pa., Code AM 303.

(1) 2-inch diameter by 1-inch long pressed pentolite pellet Federal stock No. 1375–991–8891.

(2) 12-inch long, 4-inch base, 5/8-inch apex cast, Federal stock No. 1375–991–8892.

(3) 24-inch long, 8-inch base, 5/8-inch apex cast, Federal stock No. 1375–991–8893.

5–2. Minimum Requirements. *a.* The tests given under this section are to be considered as minimum requirements. Under certain tactical siting situations or launch configurations, additional tests may be required to determine the hazard characteristics of the system. Proposed tests developed to fulfill this requirement will be coordinated with ASESB, prior to their execution.

b. When full scale tests cannot be run for economic, engineering or priority considerations, the responsible DOD Component will submit alternate test plans to the ASESB for approval or recommendations prior to the conduct of the test. The results of these tests will be given the same distribution as required by paragraph 2–3.

5–3. Application of Tests. *a.* The developing DOD Component will select the applicable tests from this chapter to determine the hazard characteristics of the end item in a particular environment (except for *c* below). It is the responsibility of the DOD Component developing a system or subsystem to determine the hazard characteristics of this system based on the specific needs. A DOD Component adopting a developed system or portion thereof need only to test to determine the hazard characteristics involved in the specific system which may differ from those tested by the developing organization.

b. Tests of combined items: When new or existing items are combined for a new application the using DOD Component will perform applicable tests from this chapter to determine the hazard characteristics of the combined system.

c. Limited quantity research items not scheduled for standard Military Service use: such items are exempt from the mandatory requirement for test under this chapter when the DOD Component wishes to accept ICC Class A and assign the appropriate military hazard classification which provides the necessary quantity-distance protection.

d. Small items containing solid propellant which are packed with more than one unit per outer container will be tested in accordance with chapter 4, table 6.

e. Items which contain a combination of propellant and explosive devices as an integral unit will be tested in accordance with applicable portions of chapters 4 and 5. Additional special tests, as required for the item concerned, will be performed.

f. Frequently siting criteria cannot be based on any single test. All applicable full scale tests, paragraphs 5–6 through 5–11, must be conducted and results considered when developing siting criteria. When siting test launch pads additional hazards such as fall-back, abort, etc., must be considered.

g. In order to determine actual hazards of the items being tested, it is necessary to conduct tests under environmental conditions which simulate those which might be encountered by the item. These environments may include heavy shipping containers, outer containers for climatic control, earth covered storage structures or even underground structures. The tests given in this chapter are to be conducted in a simulated environment which is considered to afford the maximum degree of confinement which the item normally is expected to encounter.

h. Inasmuch as fragmentation* is one of the major hazards to be expected from items to be tested under this chapter, all tests are to be conducted in a manner which will not unrealistically limit the fragment dispersal of the test configuration; i.e., cages or other devices such as thrust stands or tiedowns to impede fragment dispersal are not to be used when conducting these tests. Test configuration is to simulate as near as practicable actual conditions.

5–4. Simulated Class 7 Motors. When class 7 motors are to be used as donors for these tests, they may be simulated through the use of TNT demolition blocks or equivalent of a weight equal to 1.4 times the weight of the propellant in the motor. This explosive charge is to be inclosed within a simulated case approximating the material, weight, diameter, and length of the actual motor. Interstage hardware such as nozzles or other major fragment producing components or simulations thereof shall be positioned as in the motor.

5–5. Simulation of Electronic Gear. Surplus and/or obsolete electronics gear may be used to simulate actual electronic components provided that the amounts, sizes, and bulk densities are approximately those of equipment normally found in the guidance and control package, stage separation, etc. and that the orientation in the system is proper. Such gear may be of any type including metal casings.

5–6. Detonation Susceptibility. *a.* Motors or devices containing Class 7 solid propellants (para 3.12) will be considered ICC Class A and Military Class 7 unless the quantity of Class 7 propellant involved is so small that its detonation effects will be contained or so attenuated that the propagation of detonation to adjacent items will be prevented. The propagation test in paragraph 5–7 and applicable tests in chapter 4 will be conducted where there

*See appendix B.

is a credible chance that an item may qualify for lesser hazard classifications.

b. Motors or rocket ammunition, complete rounds (assembled or unassembled), of 8 inch diameter or less containing Class 2 or 7 propellant will be tested in accordance with tables 4 and 5 to establish hazard classifications. Motors or rockets over 8 inches in diameter containing Class 2 or 7 propellant will be tested in accordance with paragraph 5–7 to establish hazard classifications.

5–7. Propagation Test. *a.* This test is designed to determine the hazard characteristics of items under storage conditions where two or more identical units are in close proximity to each other (also see para 5–3*d* and 5–6*a*). This test need not be performed if the responsible DOD Component determines that the items involved offer little or no prospect of qualifying for a hazard classification less than Class 7.

b. This test is to be conducted with the items stacked in the expected storage arrangement. Simulated confinement equal to that which the item can be expected to encounter during storage will be provided.

c. A minimum of two items will be used in this test, however, it is recommended that additional items be included.

d. This test should be conducted in a manner which will not limit fragment dispersal of the items being tested or the simulated environment (para 5–3*h*).

e. One of the test items will be primed and initiated (internally if possible) with a 30 gram tetryl booster.

f. The primed item will be fired from a safe location. The test results will be documented as required by paragraph 2–3.

g. The results of this test may permit the assignment of a storage hazard class of 3 through 6.

5–8. Detonation Test of Multistage System, Without Warhead, in Which It Has Been Determined That at Least One Stage Is Class 7. *a.* This test is designed to determine the hazard characteristics of a multistage system under conditions where all stages are assembled together.

b. This test is to be conducted with the various stages positioned with respect to each other as would occur under the actual conditions being simulated including simulated electronic gear which is located between the various stages (para 5–5).

c. The Class 7 stage will be primed and boostered internally with sufficient explosives to assure its detonation. Where internal boostering cannot be accomplished, other means will be utilized.

d. The primed item will be fired from a safe location.

e. Documentation of the results of this test (para 2–3) will include detailed information on the damage sustained by the unprimed stages of the system.

f. The results of this test will indicate safety distances required for the multistage system, without warhead. This test will be conducted when it is desired to use safety distances less than those required by current DOD Directives when the entire assembly is considered to be hazard Class 7.

5–9. Detonation Test of Mixed Storage of Class 2 and Class 7 Items Containing Solid Propellant. *a.* This test normally will be conducted only when there are specific plans for the storage together of Class 2 and Class 7 items containing solid propellants and it is desired to use safety distances less than those required by current DOD Instructions with all items involved being considered Class 7.

b. The test is to be conducted with the items stacked in the expected storage arrangement Simulated confinement equal to that of the storage condition will be provided.

c. A minimum of one item of each hazard class will be used in this test. However, it is recommended that additional items of each class be included.

d. This test will be conducted in a manner which will not limit the fragment dispersal of the items being tested or of the simulated environment (para 5–3*h*).

e. The Class 7 item will be primed and boostered internally with sufficient explosives to assure its detonation.

f. The primed item will be fired from a safe location.

g. Documentation of the results of this test (see paragraph 2–3) will include detailed in-

formation on the damage sustained by the unprimed items.

h. The results of this test will provide a basis for quantity-distance requirements for mixed storage of Classes 2 and 7 items.

5–10. Detonation Test of Single or Multistage Systems Complete With Warhead. *a.* This test is designed to determine the effects of an accidental detonation of a warhead or warhead simulant (HE only) on the propulsion units of a system.

b. The test is to be conducted with the various stages and warhead positioned with respect to each other as would occur in an assembled system including simulated electronic gear which is located between the various stages (para 5–5).

c. Simulated confinement equal to that which may be encountered by the system will be provided for this test.

d. This test will be conducted in a manner which will not limit the fragment dispersal of the items being tested or of the simulated environment (para 5-3*h*).

e. The warhead or simulation thereof will be primed in a manner which will assure its detonation.

f. The primed item will be fired from a safe location.

g. Documentation of the results of this test (para 2–3) will include detailed information on the damage sustained by the propulsion stages of the system.

h. The results of this test will indicate safety distances required for a single or multistage system with warhead assembled.

5–11. Detonation Test of Multiple Systems. *a.* This test is intended to interrelate the effects of one complete system on a launcher or in storage to other complete systems on the same launcher or in the same storage compartment.

b. This test is to be conducted with the complete items positioned with respect to each other as normally would occur on a launcher or in storage. Simulated confinement equal to that of the condition being simulated will be provided.

c. This test should be conducted in a manner which will not limit the fragment dispersal of the items being tested or of the simulated environment (para 5–3*h*).

d. One item will be primed and boostered to assure detonation of the warhead.

e. The primed item will be fired from a safe location.

f. Documentation of the results of this test (para 2–3) will include detailed information on the damage sustained by the unprimed items.

g. Results of this test will indicate safety distances required for multiple complete systems.

5–12. Destruction Test Using Destruct System. When required, DOD Component or test range destruct test are performed on any solid propellant motor, the results of such tests will be documented. This documentation will be included with that required by paragraph 2–3.

APPENDIX A

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APPENDIX B

GLOSSARY

B-1. *Deflagration.* A rapid chemical reaction in which the output of heat is sufficient to enable the reaction to proceed and be accelerated without input of heat from another source. Deflagration is a surface phenomenon with the reaction products flowing away from the unreacted material along the surface. Confinement increases pressure, rate of reaction and temperature. The final effect of deflagration under confinement is explosion.

B-2. *Detonation.* A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and high pressures. A detonation, in contradistinction to deflagration, is the reaction which proceeds through the reacted material toward the unreacted material at a high constant velocity. The velocity of the reaction is supersonic. The result of the chemical reaction is exertion of extremely high pressures on the surrounding medium forming a pressure wave (blast wave) which propagates away from the source at supersonic velocities. A detonation, when the material is located on or near the surface of the ground, is normally characterized by a crater.

B-3. *Explosion.* A chemical reaction of any chemical compound or mechanical mixture which, when subjected to heat, friction, shock, or other suitable initiation, undergoes a very rapid combustion or decomposition releasing large volumes of highly-heated gases which exert pressures on the surounding medium. Also, a mechanical reaction in which failure of the container causes the sudden release of pressure from within a pressure vessel, for example, pressure rupture of a steam boiler. Depending on the rate of energy release, an explosion can be categorized as a deflagration, a detonation or pressure rupture.

B-4. *DOD Components.* Includes all DOD Agencies and Departments.

B-5. *Fragmentation.* The breaking up of the confining material of a chemical compound or mechanical mixture when an explosion takes place. A deflagration usually reduces the confining material into large pieces which are projected at low velocities whereas a detonation reduces the confining material into small pieces which are projected at high velocities. Also, complete items, subassemblies or pieces thereof as well as pieces of equipment or buildings containing the items.

B-6. *Responsible DOD Components.* The Headquarters of the DOD Department or Agency responsible for the development or use of the item concerned.

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